

Appendix A

Executive Order Establishing the New York Climate Action Council

In August of 2009 Governor David A. Paterson signed Executive Order No. 24 setting a goal to reduce greenhouse gas emissions in New York State by 80 percent below the levels emitted in 1990 by the year 2050. The Executive Order also created the [New York Climate Action Council](#) with a directive to prepare a draft Climate Action Plan by September 30, 2010. Executive Order No. 24 is copied below.

Executive Order No. 24: ESTABLISHING A GOAL TO REDUCE GREENHOUSE GAS EMISSIONS EIGHTY PERCENT BY THE YEAR 2050 AND PREPARING A CLIMATE ACTION PLAN

WHEREAS, an emerging scientific consensus recognizes that the increased concentration of carbon dioxide in the atmosphere, along with other heat-trapping greenhouse gasses, resulting from the combustion of fossil fuels and other human sources, warms the planet and changes its climate; and

WHEREAS, many scientists warn that unmitigated climate change is expected to result in significant adverse impacts to our communities, economy and environment; and

WHEREAS, according to the scientific assessments of the United Nations Intergovernmental Panel on Climate Change, and other work, substantial reductions in greenhouse gas emissions by mid-century have the potential to minimize the most severe climate change impacts currently predicted; and

WHEREAS, the reduction of global warming and limitation of climate change effects requires a collaborative, international effort to reduce the emission of greenhouses gases around the globe; and

WHEREAS, New York and other states should work collaboratively with the federal government to develop and implement plans and policies that will achieve reductions in greenhouse gas emissions in the United States; and

WHEREAS, expanding and advancing energy efficiency and renewable energy projects will reduce greenhouse gas emissions and create new jobs; and

WHEREAS, New York State has demonstrated leadership in this effort by undertaking actions such as:

- Executive Order No. 2 (2008): [Establishing a State Energy Planning Board and Authorizing the Creation and Implementation of a State Energy Plan](#);

- Executive Order No. 4 (2008): [Establishing a State Green Procurement and Agency Sustainability Program](#);
- Creation of the Governor's Smart Growth Cabinet;
- Adoption of goals and practices for energy efficiency and green building technology in State buildings, and for the use of biofuels in State vehicles and buildings;
- Creation of the New York State Office of Climate Change in the New York State Department of Environmental Conservation;
- Participation in the Regional Greenhouse Gas Initiative, a ten-state cooperative effort to reduce greenhouse gas emissions from electric power plants by means of a cap and trade system;
- Creation of an Energy Efficiency Portfolio Standard, which is intended to reduce the State's electricity consumption by 15 percent below projected levels by 2015, complementing the State's System Benefit Charge and Renewable Portfolio Standard;
- The formation of a Renewable Energy Task Force and a Sea Level Rise Task Force;
- Collaboration with other northeastern and mid-Atlantic states on the development of a regional low carbon fuel standard;
- Establishment of a "45 x 15" Initiative, which set a goal to meet 45% of New York's electricity needs through improved energy efficiency and clean renewable energy by 2015;
- Adoption of regulations establishing greenhouse gas exhaust emission standards for motor vehicles;
- Enactment of legislation requiring new motor vehicles to bear labels disclosing information to consumers about vehicle greenhouse gas emissions;
- Enactment of legislation establishing "green" residential and State building programs;
- Enactment of legislation expanding the State's "net metering" laws, allowing increased development of renewable energy by electricity customers;
- Enactment of Legislation expanding energy efficiency and clean energy initiatives of the New York Power Authority to public entities; and
- Investment of billions of dollars by the New York State Energy Research and Development Authority, the New York Power Authority and the Long Island Power Authority in existing, expanded and new energy efficiency and renewable energy programs; and

WHEREAS, it is appropriate to build upon the important environmental benefits obtained through these actions and to establish a State-wide goal for the reduction of greenhouse gasses, and to develop a plan that enables New York to participate fully in the national and international efforts to combat climate change.

NOW, THEREFORE, I, David A. Paterson, Governor of the State of New York, by virtue of the authority vested in me by the Constitution and laws of the State of New York, do hereby order as follows:

1. It shall be a goal of the State of New York to reduce current greenhouse gas emissions from all sources within the State eighty percent (80%) below levels emitted in the year nineteen hundred ninety (1990) by the year two-thousand fifty (2050).
2. There is hereby created a Climate Action Council (“Council”) consisting of the Commissioners of Agriculture and Markets, Economic Development, Environmental Conservation, Housing and Community Renewal, and Transportation; the Chairs of the Public Service Commission, and Metropolitan Transportation Authority; the Presidents of the New York State Energy Research and Development Authority, Long Island Power Authority, New York Power Authority and Dormitory Authority of the State of New York; the Secretary of State; the Director of the Budget; the Director of State Operations; and the Counsel to the Governor. The Director of State Operations shall serve as the Chair of the Council.
3. The Council shall prepare a draft Climate Action Plan on or before September 30, 2010. The Council shall hold regional public comment hearings on the draft Plan, and shall allow at least 60 days for the submission of public comment. Thereafter, the Council shall prepare a final Climate Action Plan which shall be reviewed and, if warranted, adjusted annually by the Council.
4. In aspiring to meet the greenhouse gas emission reduction goal, the Council, in preparing the Climate Action Plan, shall:
 - a. inventory greenhouse gas emissions within the State, including the relative contribution of each type of emission source;
 - b. identify and assess short-term and long-term actions to reduce greenhouse gas emissions and adapt to climate change across all economic sectors, including industry, transportation, agriculture, building construction and energy production;
 - c. identify and analyze the anticipated reductions, and the economic implications thereof, as a result of each action;
 - d. identify the anticipated life-cycle implications, consequences, benefits and costs of implementing each action, including implications, consequences, benefits and costs to the State, local governments, business and residents from implementation of each option and action;
 - e. identify whether such actions support New York’s goals for clean energy in the new economy, including specific short-term and long-term economic development opportunities and disadvantages related to greenhouse gas emission reductions and the development and deployment of new and emerging technologies and energy sources;
 - f. coordinate its activities with the State energy planning process of the State Energy Planning Board;

- g. identify existing legal, regulatory and policy constraints to reducing greenhouse gas emissions, assessing the impacts of climate change, and adapting to climate change, and recommend ways to address any such constraints;
 - h. establish estimated timelines for considering and implementing actions; and
 - i. undertake such actions, and compile such additional material, as deemed appropriate by the Council in carrying out its responsibilities under this Order.
5. Members of the Council may designate an executive staff member to represent them and participate on the Council on their behalf, subject to the approval of the Chair. A majority of the members of the Council shall constitute a quorum, and all actions and recommendations of the Council shall require approval of a majority of the total members or their representatives.
6. The entities represented on the Council are authorized to provide the primary staff and other resources that are necessary for the Council to comply with this Order. In addition, every other agency, department, office, division and public authority of this State shall cooperate with the Council and furnish such information and assistance as the Council determines is reasonably necessary for it to comply with this Order.
7. The Council may convene advisory panels to assist or advise it in areas requiring special expertise or knowledge.
8. The Climate Action Plan is not intended to be static, but rather a dynamic and continually evolving strategy to assess and achieve the goal of sustained reductions of greenhouse gas emissions.

G I V E N under my hand and the Privy Seal of the State in the City of Albany this sixth day of August in the year two thousand nine.

David A. Paterson
Governor

Lawrence Schwartz
Secretary to the Governor

Appendix B

Description of New York State Climate Action Council Process

Creation of the New York State Climate Action Council

In August 2009, Governor David A. Paterson signed [Executive Order 24](#) establishing the goal of reducing greenhouse gas (GHG) emissions from all New York sources to 80 percent below 1990 levels by 2050 and creating the New York State Climate Action Council (Council). The purpose of the Council is to assist New York in identifying the best opportunities to mitigate and adapt to climate change, reduce costs associated with climate change activities, and foster economic growth in New York.

The Council's Response to Date: In fulfillment of the requirements of the Executive Order, the Council has held six meetings between November 2009 and December 2010, and formed three external panels to assist and advise in areas requiring special expertise or knowledge: Technical Analysis, which consists of five Technical Working Groups; Multi-Sector Integration; and 2050 Visioning.

For planning and progress benchmarking purposes, the Council adopted an interim GHG reduction goal of 40 percent below 1990 levels by 2030, or one-half of the 80 by 50 goal at the mid-point between 2010 and 2050.

The Council and supporting panels crafted sector-specific vision statements that describe the major characteristics of each mitigation and adaptation sector in 2050 as necessary or desirable to achieve the 80 by 50 goal.

The Council and supporting panels reviewed over 300 multi-sector GHG mitigation policy options and approved for inclusion in this Report a package of draft mitigation policy options to reduce GHG emissions and address related energy and economic issues in New York State. Many of these draft recommendations have been individually analyzed for their likely GHG reduction potential and net direct cost or savings to the New York economy.¹

The Council and supporting panels performed a systematic review of vulnerabilities to the effects of climate change and approved draft adaptation policy recommendations across eight sectors for inclusion in this Report.

The Climate Action Plan Process

The Council began the formal deliberative process at the first meeting of the Integration Advisory Panel and Technical Working Groups on January 14, 2010. The Integration Advisory Panel has met in person five times, and the five Technical Work Groups have met in person and

¹ Integrated analysis of the policies which takes into consideration policy interactions and overlaps, as well as macroeconomic, or indirect economic impacts on income, GSP, employment and prices, will be completed in the next phase of the Plan process.

by teleconference bi-weekly since January 2010. The five Technical Work Groups considered potential policy options in the following sectors:

- Power Supply and Delivery (PSD)
- Residential, Commercial/Institutional, and Industrial (RCI)
- Transportation and Land Use (TLU)
- Agriculture, Forestry, and Waste Management (AFW)
- Adaptation (ADP)

The four Mitigation Technical Work Groups (PSD, RCI, TLU, and AFW) focused on opportunities to mitigate GHG emissions or enhance the sequestration of atmospheric carbon dioxide within their respective sectors. The fifth, the Adaptation Technical Work Group, focused on policies that anticipated highly likely climate impacts over the next 100 years in eight economic and natural resource sectors, seeking to enhance potential benefits and reduce the cost and security risks associated with unavoidable climate impacts.

New York State agency participation has been extensive throughout the process, with project leadership and coordination provided by the [New York Energy Research and Development Authority](#) (NYSERDA) and the [Department of Environmental Conservation](#) (DEC). The [Center for Climate Strategies](#) provided facilitation and technical assistance to the process, including facilitation and technical support for each of the Technical Work Groups, based on a detailed proposal approved by NYSERDA.

The Technical Work Groups served as advisors to the Council and consisted of Council member agency staff and additional public, private and non-profit sector stakeholders with specific interest and expertise. Members of the public were invited to observe and provide input at all meetings of the Integration Advisory Panel and Technical Work Groups. A series of four public informational meetings were held around the State during the process. Planning process documents and deliberative and analytical products were posted to the Plan's public web site, which also provided an additional venue for public input.

Prior to a joint organizational meeting of the Integration Advisory Panel and Technical Work Groups the appointed participants attended a "2050 Visioning Conference" hosted by the [New York Academy of Sciences](#) and organized by [Brookhaven National Laboratory](#). The focus of the conference was to place the challenge of the 80 by 50 goal into real-world context, and by example illustrate the kinds of transformational change needed to achieve the goal.

After getting organized and reviewing the preliminary inventory and forecast the Technical Work Groups crafted sector-specific vision statements with supplemental text providing detail about the sector's demand for and use of energy, as well as advisory comments on related matters.

Mitigation Policy Process: Following the development of the vision statements, the four Mitigation Technical Work Groups then generated an additional set of New York State-specific policy options to be added to the catalog of existing states actions. Catalog policies were reviewed by representatives of the environmental justice community and participants in

NYSERDA's ClimAID project with written comments added to each policy in the catalog reflecting their concerns for whether and how the policy might affect disadvantaged communities, or be affected by anticipated near-term climate effects.

Where available, an estimate of the general potential for each cataloged mitigation policy to reduce GHG emissions in New York and a rough estimate of the direct cost or savings per ton of emissions reduced were provided to Technical Work Group members. Most of these estimates were derived from research sponsored by NYSERDA and conducted by the Center for Climate Strategies, titled [*Development of New York State Greenhouse Gas Abatement Cost Curves*](#).

Technical Work Group members also scrutinized and recommended enhancements to the New York State inventory and forecast of GHG emissions developed by NYSERDA with assistance from the Center for Climate Strategies (contained in the *New York Greenhouse Gas Emissions Inventory and Forecast* report and summarized in Chapter 3). The inventory, which begins in 1990, serves as the benchmark against which progress toward the 80 percent below 1990 emissions levels goal is measured. The forecast serves as the baseline or 'business-as-usual' projection of future emissions assuming no measures to reduce them are enacted beyond those already in place or approved.

The inventory and forecast and the analysis of most mitigation policies cover the six types of gases included in the United States (U.S.) Greenhouse Gas Inventory: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). The inventory and reference case projections include detailed coverage of all economic sectors and GHGs in New York State, including future emission trends related to energy, the economy, and population growth.

Once the Technical Work Groups had settled upon their broad sector visions for 2050, commented on the draft inventory and forecast, and reviewed the technical potentials and anticipated environmental justice and climate impact implications of the catalog policies, members engaged in a process of selecting priority policies for development and analysis. This process allowed the Technical Work Groups to regroup the catalog policies into logical policy bundles organized around sets of technologies, e.g., renewable electricity generation, or policy instruments, e.g., a renewable portfolio standard.

Technical Work Group-proposed priorities were reviewed by the Integration Advisory Panel and Council, ultimately yielding 39 priority policy bundles across the four mitigation sectors. The Technical Work Groups then set about the task of defining each policy as it could be implemented in New York State and specifying GHG reduction goals and timing. Each policy was developed using a template calling for:

- Policy Description
- Policy Design
- Implementation Mechanisms
- Related Policies and Programs in Place
- Estimated GHG Reductions and Costs or Cost Savings

- Key Uncertainties
- Additional Benefits and Costs
- Adaptation to Climate Change Considerations (if any)
- Environmental Justice Considerations (if any)
- Feasibility Issues

Once the policy design, goals and timing were settled, the Center for Climate Strategies analysts began to analyze the priority policy bundles designated for quantification. The analytical assumptions, data sources and methods were carefully reviewed and revised as needed by NYSERDA, DEC, other participating State agencies and Technical Work Group members. In some cases, multiple scenarios or sensitivity analyses were produced for policies or sub policies, and, depending on the results, policy designs were sometimes adjusted by the Technical Work Groups in response to the first analysis.

The four Mitigation Technical Work Groups have met in person or by teleconference bi-weekly through October 2010, not including small group meetings. Chapters 6 through 9 contain summaries of these mitigation policies including their analytical results. The analytical results presented here describe the potential effectiveness of the mitigation policies on a stand-alone basis; that is, it is assumed each policy is being implemented in isolation, and that none of the other recommended policies are implemented as well. This analysis generally does not consider interactions among policies or overlapping emissions reductions. It is therefore not appropriate to sum up the reductions or costs associated with individual policies in this Report to estimate a cumulative result.

Adaptation Policy Process: Unlike mitigation climate action planning, which has been undertaken in over 20 states and for which generally accepted methods have been developed, adaptation policy development is relatively new. A few other states have examined the adaptation challenge, but prior to the New York Climate Action Plan no state had attempted the comprehensive effort to investigate likely unavoidable climate impacts across eight sectors, assess their social, environmental, public health and economic risks, and propose dozens of measures to address them.

While there are many similarities, the Adaptation Technical Work Group followed a different process than that described above for the Mitigation Technical Work Groups. The Adaptation Technical Work Group was divided into eight sector subgroups as follows:

- Agriculture
- Ocean Coastal Zones
- Ecosystems
- Water Resources
- Public Health
- Transportation

- Energy
- Communications

Like the Mitigation Technical Work Groups, each Adaptation Technical Work Group subgroup crafted their own 2050 vision statement and then followed a formal process to guide the formation of recommendations. Informing this process were the draft results of the ClimAID research funded by NYSERDA and conducted by teams from Columbia and Cornell Universities, and the City University of New York, as well as the State Sea Level Rise Task Force and elements of New York City's PlaNYC.

The goals of the adaptation policies are somewhat different from the mitigation goals. Recommended adaptation policies seek to address one or more of the following:

- Prepare, protect, or improve climate resiliency
- Improve climate monitoring, surveillance and data collection
- Improve decision-making tools to enhance incorporation of climate projections in decision-making, permit and design criteria
- Evaluate and enhance New York's capacity to respond, e.g., through climate-informed emergency response plans and protocols
- Develop new strategies and promote advances in related technology through research and development
- Promote the inclusion of climate science in education curricula and other forms of educational outreach
- Improve coordination among federal, regional, state and local governments
- Identify and address equity issues

The Adaptation Technical Work Group created its own policy description template to fully describe their policy proposals and evaluate them according to criteria developed by the group. The adaptation policy template included the following:

- Climate Variables and Probabilities
- Impacts on Resources (Likelihood, Consequence, Magnitude)
- Timing of Risk and Overall Risk
- Adaptation Strategy
- Policy/Mechanism (Who, What, Where, How)
- Potential Cost
- Feasibility
- Timing of Implementation
- Efficiency

- Resiliency
- Environmental Justice Considerations (Distribution, Degree)
- Co-benefits and Costs
- Research/Information Needs

The Adaptation Technical Work Group has developed policy recommendations across the eight sectors, which are summarized in Chapter 11. The full Adaptation Technical Work Group met by teleconference 12 times since January 2010, with one in-person meeting, and the eight subgroups met dozens of times separately to develop their recommendations. As with the mitigation policies, the Integration Advisory Panel and the Council reviewed and commented on the adaptation policy sets as they were being developed.

Public Engagement: Key to the Climate Action Plan process design is the active engagement of the public. As shown in Appendix C, the Technical Work Groups and Integration Advisory Panel count among their members many representatives of environmental justice communities, business and industry, academia, non-government organizations, trade associations, regional and local governments, and state agencies. In addition to appointed membership on process committees, four public informational meetings were held including two with special focus on environmental justice concerns. An informational webinar will be provided, and three public hearings will be held to solicit comment on this Interim Report.

To facilitate ongoing public involvement, all Technical Work Group and Integration Advisory Panel meeting summaries, documents, drafts and work products were posted to the public web site www.nyclimatechange.us, which provided an opportunity to submit electronic comments or questions. In addition, every Technical Work Group and Integration Advisory Panel meeting or teleconference was open to the public, and each meeting agenda provided an opportunity for public comment or question.

In addition to the multiple public engagement opportunities described above, those living in economically disadvantaged communities have been represented and their concerns voiced through formal integration of environmental justice concerns throughout the process. Through representation on the Integration Advisory Panel and Technical Work Groups, and by incorporation of written comments and guidance at key junctures in the deliberations, the authors of these recommendations have heard and sought to incorporate these concerns into the policy designs.

In all, dozens of comments were received during Technical Work Group conference calls, about 25 comments and other inquiries were received through the web site portal, and approximately 125 people attended the first four informational meetings.

Next Steps

While the identification of mitigation and adaptation policies for New York and the quantification of a subset of these for their GHG reduction potential and cost is a major achievement, to fully satisfy Executive Order 24 more must be done. Public comment on this Interim Report will be taken for a 90-day period, during which three public hearings will be held.

Comments received will be reviewed by the Council and addressed in the draft Climate Action Plan as appropriate.

This Report identifies cross-sector policies and issues (Chapter 12), but the analysis contained here assumes each policy is implemented in isolation. The next phase of the planning process will consider all policy interactions and produce a methodologically correct ‘sum of the parts’ projection for Action Plan emission reduction potentials and costs.

Also to be included in the next phase is a macroeconomic analysis of the impact of the recommended policies on the broader New York economy. Costs and savings associated with policies in this Report consider only the direct costs and savings to society, defined as within the geographic boundaries of New York State. Secondary, indirect, or macroeconomic impacts such as statewide employment, income, energy price and Gross State Product impacts will be examined next with the results presented in the Final Climate Action Plan Report.

Many climate-sensitive policies are not new. Indeed, much progress has already been achieved through enactment of measures unrelated to climate concerns. Energy efficiency has long been both an economic and national security priority; the GHG benefits are considered ‘co-benefits’ of these policy goals. Likewise, many of the policies recommended here offer co-benefits of their own. In particular, efforts that result in reduced burning of fossil fuels often result in lowered emissions of pollutants other than CO₂. Criteria pollutants, such as particulates, sulfur dioxide, nitrogen oxides and air toxics emissions, may also be mitigated by climate-driven actions. Some of these pollutants adversely affect human health and, therefore, impose economic and societal costs. To more completely assess the value of these policies, the next phase of this planning process will include a co-benefits analysis to project the level of non-CO₂ pollutant reductions and estimate the related benefits in improved human health and reduced cost associated with treating resulting illnesses.

As discussed in Chapter 14, some of the most effective actions New York State could pursue would either require or greatly benefit from the participation of our regional neighbors or the federal government. Following the issuance of the Final Climate Action Plan Report in 2011, the State will move toward implementation of the Plan, which will require engagement with regional neighbors and the federal government on a variety of policy recommendations.

Critical to the charge of Executive Order 24 is demonstrating that the policies proposed here, after enhanced analysis and refinement, can achieve the goal of total statewide emissions 80 percent below New York State emissions in 1990. The analysis contained here covers the period from 2010 through 2030. Some key policies have also had GHG reductions estimated between 2030 and 2050, but cost estimates are limited to the next twenty years due to the increasing uncertainty associated with longer-range projections. The Final Climate Action Plan Report will therefore contain an additional analysis showing whether the 2050 goal will be achieved by the implementation of the Plan’s recommendations.

Appendix C

Members of the Integration Advisory Panel and Technical Work Groups

New York Climate Action Plan Process Integration Advisory Panel

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Appendix D

Overview of Current New York State Climate and Energy Policies

New York State has initiated or participates in programs on regional, state, and local levels that reduce greenhouse gas emissions and encourage energy independence, energy efficiency and renewable energy.

Greenhouse Gas Inventory and Reduction

The Regional Greenhouse Gas Initiative (RGGI)

New York is one of ten Northeastern and Mid-Atlantic states participating in the RGGI cap and invest program. The New York CO₂ Budget Trading Program (6NYCRR Part 242) and the CO₂ Allowance Auction Program (21NYCRR Part 507) took effect January 1, 2009. Emissions of carbon dioxide from electric power generating facilities will be reduced ten percent by 2018. Auction proceeds support statewide investments in energy efficiency, renewable and clean energy, and innovative carbon abatement technologies, as guided by the RGGI Operating Plan.

The Climate Registry

The Climate Registry is a partnership of businesses, environmental organizations and states with standards for estimating and reporting greenhouse gas emissions (carbon dioxide (CO₂), methane, nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)). Twenty-one New York public and private organizations have enrolled as Founding Reporters and committed to inventory and report their emissions under the Registry's protocol.

Adoption of California Vehicle Emissions Standards

California is the only state that is not preempted by federal vehicle emissions standards and, as a result, is permitted to set stricter standards than those that apply to the nation as a whole. Once a rule has been adopted in California, other states seeking standards for a higher level of emissions controls are permitted to adopt such California standards as well. New York has adopted the most recent California standards, which would reduce greenhouse gas emissions from cars by 37 percent and from light trucks 24 percent by 2016.

Regional Low-Carbon Fuel Standard

The Regional Low-Carbon Fuel Standard is a market-based, technologically neutral emissions-performance standard under development by 11 Northeast and Mid-Atlantic states (Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Pennsylvania) that will reduce the carbon intensity of transportation fuels sold in the region.

The Transportation and Climate Initiative

This initiative is a coordinated regional effort by 12 Northeast and Mid-Atlantic jurisdictions (Connecticut, Delaware, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, Rhode Island, Vermont, Pennsylvania, and the District of Columbia) to reduce transportation sector greenhouse gas emissions and further the development of a clean energy economy. The participating jurisdictions are working to reduce greenhouse gas emissions, minimize our transportation system's reliance on high-carbon fuels, promote sustainable growth, address the challenges of vehicle miles traveled, and help build the clean energy economy.

Climate Smart Communities

This program includes ten-point pledge for municipalities to reduce greenhouse gas emissions, prepare for climate change, and invest in green economies. Launched February 2009, the Climate Smart Communities Pledge has already been adopted by at least 85 New York communities.

Office of Climate Change

The charge of the Office of Climate Change is to lead development of programs and policies that mitigate greenhouse gas emissions and help municipalities and individuals adapt to the effects of climate change. In addition to implementing RGGI, the Office is developing the full suite of responses needed for significant emissions reductions and for successful adaptation to changing temperatures, sea levels, precipitation and other climate factors.

Energy Efficiency and Renewable Energy

45 by 15

Adopted in the 2009 State Energy Plan, this energy policy is designed to meet 45 percent of New York's electric energy needs from energy efficiency and renewable energy by the year 2015. Along with program requirements from the State's energy authorities, this policy is implemented by two key programs:

Renewable Portfolio Standard (RPS)

This program requires 30 percent of electricity in New York to be supplied from renewable energy sources by 2015 and provides financial incentives to support development of renewable energy sources. To date, the RPS has led to the development of over 1300 MW of renewable power including large-scale facilities and thousands of customer-sited renewable resources. New York is one of 27 states to use a RPS to drive a transition to renewable sources of electricity.

Energy Efficiency Portfolio Standard (EEPS)

This program is designed to contribute to reducing energy demand **15 percent** from forecasted levels by 2015, through energy efficiency. This program is expected to provide more than \$4 billion in benefits to customers, along with thousands of jobs to support energy efficiency programs, such as retrofitting outdated and inefficient residential, commercial and industrial properties and installing new energy efficient equipment. Additional energy efficiency gains are anticipated to contribute to the 15 percent

reduction also include strengthening efficiency standards for appliances and buildings, and address energy efficiency opportunities for New York's largest energy consumer – State government.

System Benefits Charge (SBC)

The System Benefits Charge supports the implementation of a portfolio of energy efficiency and clean energy activities. The SBC program provides New York-based investment in research, development and demonstration of emerging energy technologies, supports business development of new companies that are providing innovative products and services, and provides support for accelerating the introduction into the market and use of energy efficiency and clean energy technologies. This program also provides targeted energy efficiency services for low-income customers.

Green Buildings

The Green Buildings Tax Credit Program provides state tax credits to owners and tenants of eligible buildings that meet certain energy and environmental performance standards. Large commercial and residential buildings that meet these standards will have lower environmental impacts than buildings that would otherwise meet a lower level of performance, based on existing building codes. The program is also designed to provide general information and foster contacts among building design teams and building owners to help new and rehabilitated commercial, industrial, and institutional buildings achieve higher levels of energy and environmental performance. In addition to the tax credit program, a new incentive program to foster interest in high-performance single-family residential buildings has also been initiated.

Renewable Energy Task Force

Comprised of 20 private-sector and government representatives, the Renewable Energy Task Force issued a Report in February 2008, listing 16 specific policy and program recommendations which constitute a roadmap to significantly increase the use of renewable energy in New York. Recommendations include greater solar energy production, expanding the State's RPS, and business incentives to attract renewable energy producers and expand the State's "green collar" workforce. This Report has launched several successful initiatives, including the Vehicle Miles Traveled Task Force, a Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply For New York¹, and other projects which will provide the foundation to advance the recommendations into sound energy and environment programs.

Net Metering

Net Metering allows electricity customers with qualified renewable energy systems – including home-based solar and wind systems and farm-based waste digester systems – to sell excess electricity generated by such facilities to the local utility. Several 2008 laws authorized expansion of the existing programs, increasing the maximum amount of energy that utilities are required to buy from host energy sites through net metering.

¹ NYSERDA Report 10-05. April, 2010.

State Operations Policies

Designed to affect State government operations and improve the energy and environmental performance of State assets and resources, several programs have been initiated and implemented through Executive Order (EO). These EO actions include:

Green and Clean State Buildings and Vehicles Guidelines (EO 111)

EO 111 requires State buildings to reduce energy consumption by 35 percent of 1990 levels by 2010, and mandates that State agencies select ENERGY STAR qualified products. Construction and renovations must follow Leadership in Energy and Environmental Design (LEED) green building standards.

State Green Procurement and Agency Sustainability Program (EO 4)

EO 4 promotes the State purchase of environmentally-friendly commodities, services and technologies, as well as agency sustainability and stewardship programs.

Use of Biofuels and Alternative Fueled Vehicles (EO 142)

EO 142 requires State agencies to phase in renewable heating and transportation fuels. The State is working to assess the environmental, social, and health effects of biofuels and has developed a Renewable Fuels Roadmap that lays out a sound future for New York in this area.

Climate Change Adaptation

New York State Sea Level Rise Task Force

The Sea Level Rise Task Force was created by the State Legislature in 2007 to assess sea level rise effects to the State's coastlines and to recommend protective and adaptive measures for coastal communities and natural habitats. The Task Force will produce a report of recommendations by January 1, 2011.

NYS Interagency Local Government Adaptation Workgroup

This ad hoc workgroup facilitates development of recommendations for local adaptation planning, decision-support tool development and cooperative management of pilot projects.

State Wildlife Action Plan (SWAP) Vulnerability Assessments

These habitat type vulnerability assessments and assessments of threats to species of special concern identify potential actions for SWAP.

Appendix E

Methods of Quantification

The Climate Action Plan used an overall analytical approach applied across the four greenhouse gas mitigation sectors. Key elements of the overall approach are described in the Quantification Methods Memorandum. The key elements are divided into the following three sections: Overall Approach, GHG Emissions and Emission Reductions, and Cost Analysis Methods. Separate memoranda, the “Common Assumptions Memos,” focus on key analytical methods that are specific to each of the four Technical Work Group areas, and follow the Quantification Methods Memorandum.

Draft Quantification Methods Memorandum

New York State Climate Action Plan

Prepared for:

**The New York State Energy Research and
Development Authority**

and

**The New York State Department of
Environmental Conservation**

Albany, NY

Prepared by:

The Center for Climate Strategies (CCS)

July 23, 2010

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INTRODUCTION

The purpose of the Quantification Memorandum is to explain the methodologies and identify key assumptions for developing sector-specific estimates of greenhouse gas (GHG) emission reduction potential, incremental costs, and cost effectiveness for Climate Action Plan recommended policies for New York. This memorandum also addresses the data sources/types and methods that will be needed to support the analysis of sector-specific GHG mitigation policy options associated with statewide implementation of aggregated technologies and best practices.

The first part of this memorandum discusses key elements of the overall analytical approach that apply across all four Technical Work Group sectors. The key elements are divided into the following three sections: Overall Approach, GHG Emissions and Emission Reductions, and Cost Analysis Methods. Separate memoranda, the “Common Assumptions Memos,” focus on key analytical methods that are specific to each of the four Technical Work Group areas.

Overall Approach

Emission Sources

The project was divided into four Technical Work Group sectors to analyze the emission reduction potential and associated costs of individual GHG mitigation policy options and reflect the relationship between reduction potentials and cost per metric ton of carbon dioxide equivalent (CO₂e) emissions avoided. The four sectors include:

- (1) Residential, Commercial/Institutional, and Industrial (RCI);
- (2) Power Supply and Delivery (PSD);
- (3) Transportation and Land Use (TLU); and,
- (4) Agriculture, Forestry, and Waste Management (AFW).

The analysis of policy options will focus on those that are or may be applicable in New York State. When relevant, and as allowed by the availability of data, budget and project time, the analysis will include geographic differences in the application and costs of mitigation policies (e.g., New York City versus the rest of the state). At a minimum, in-state emission reductions and costs will be estimated for technologies and best practices as applied in New York State.

Subject to review by the Integration Advisory Panel, emission reductions will also be estimated for technologies and best practices applied within the state that result in emission reductions outside of the state. For instance, a major benefit of recycling is the reduction in material extraction and processing (e.g., aluminum production). While a policy may increase recycling in New York, the reduction in emissions may occur where this material is produced. Where significant emissions impacts are likely to occur outside the state, this will be clearly indicated. However, for the purpose of counting emissions reductions against New York’s goal, only in-state reductions will be included.

Fuel Cycle Coverage

For the purposes of this study, the full fuel cycle represents the range of activities associated with fuel extraction, processing, distribution, and consumption. For the PSD, RCI, AFW and TLU sectors, GHG reductions for each mitigation policy option will be based upon the full fuel cycle because information is available to support this type of analysis for these sectors. Tracking the full range of fuel use inputs is essential for accurately tracking fuel cycle carbon emissions for technology options displaying very different performance characteristics. The approach involves identifying all the possible stages of the fuel cycle and quantifying the fuel input per unit of energy produced (electricity or fossil fuel).

Fuel cycle impacts will be reported for each source for which information is available to support a fuel cycle analysis. Where fuel cycle emission reductions are captured, there will often be two sets of emission reductions estimated: the total fuel cycle reductions; and those estimated to occur within the state. For the purpose of counting emissions reductions against New York's goal, only in-state reductions will be included. In most cases, these will be difficult to separate based on available information. Therefore, by default, the in-state reductions will often be those associated with fuel combustion and known in-state processes. Emission reductions from in-state processes associated with non-combustion reduction sources include only those processes that are known to occur within New York State (e.g., landfill emission reductions, but not the upstream GHG emissions embedded in the waste component) and exclude processes where the geographic origin of the mitigated emissions is uncertain (e.g., emissions from extraction/processing/packaging of virgin materials into usable products).

Life Cycle Coverage

For the purposes of this quantification, life cycle represents the energy and materials used for manufacture, its energy use during useful life, and disposal and/or capacity to be recycled. As the Climate Action Plan Council has conveyed interest in reporting in-state GHG reductions – with fuel-cycle reductions considered as co-benefits – full life cycle analyses may not be performed. Should sufficient data and parameters become available to execute a full life cycle analysis, CCS will include life cycle analysis, listing life cycle GHG reductions as co-benefits.

Pollutant Coverage and Global Warming Potentials

The analysis will cover the following six GHGs: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). Emissions of these gases will be presented using a common metric, CO₂e, which accounts for the relative contribution of each gas to global average radiative forcing by multiplying the emissions of each pollutant by its Global Warming Potential (GWP)—a unitless factor representing the ratio of the radiative forcing of each GHG to the radiative forcing of CO₂ (the GWP for CO₂ is 1). Table E-1 shows the 100-year GWPs published by the Intergovernmental Panel on Climate Change (IPCC) in its Second, Third, and Fourth Assessment Reports. To be consistent with the GHG emissions inventory and forecast for the state of New York, the 100-year GWP's published in the Second Assessment Report of the IPCC will be used to convert mass emissions to a 100-year GWP basis. Use of the 100-year GWP's published in the IPCC's Second Assessment Report is also consistent with U.S. Environmental Protection Agency (EPA) and IPCC guidance for consistency with how U.S. national, state, and country-specific GHG emissions inventories have been developed in the past.

Qualitative information on the criteria air pollutants and toxic air pollutants will also be included when this information is identified for individual technologies and practices in order to support co-benefits analysis.

Table E-1. 100-Year Global Warming Potentials from the Second, Third and Fourth Assessment Reports of the IPCC

Gas	100-year GWP (2nd Assessment) ¹	100-year GWP (3rd Assessment) ²	100-year GWP (4th Assessment) ³
CO ₂	1	1	1
CH ₄	21	23	25
N ₂ O	310	296	298
HFC-23	11,700	12,000	14,800
HFC-125	2,800	3,400	3,500
HFC-134a	1,300	1,300	1,430
HFC-143a	3,800	4,300	4,470
HFC-152a	140	120	124
HFC-227ea	2,900	3,500	3,220
HFC-236fa	6,300	9,400	794
HFC-4310mee	1,300	1,500	1,640
CF ₄	6,500	5,700	7,390
C ₂ F ₆	9,200	11,900	12,200
C ₄ F ₁₀	7,000	8,600	8,860
C ₆ F ₁₄	7,400	9,000	9,300
SF ₆	23,900	22,200	22,800

* The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor.

An inventory for elemental (black) carbon (EC) and organic carbon (OC) will also be developed, so that potential co-benefits related to climate forcing and regional haze can be assessed, at least in a semi-quantitative fashion. CCS will use methods that it has used in several other states to develop a base year and projection year EC/OC inventory.

Time Period of Analysis

Fuel cycle emission reductions and incremental costs will be calculated relative to the characteristics of the baseline that would otherwise prevail in New York up through the end of the planning period, 2030.

¹Second Assessment: http://www.epa.gov/climatechange/emissions/downloads/ghg_gwp.pdf 1995. Because only a summary of the Second Assessment Report is available online, an EPA document is cited which has the table from the IPCC report.

²Third Assessment: <http://www.ipcc.ch/ipccreports/tar/wg1/248.htm>, 2001.

³Fourth Assessment: <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf>, 2007.

The analysis will report annual emission reductions for 2020 and 2030. The present value of the cumulative incremental costs, and undiscounted cumulative CO₂e emission reductions, will be reported for the period starting with the initial year of the phase-in of the policy, up through 2030. For example, if an RCI policy includes a complete phase-in over time of more efficient plug load technologies (i.e., computers, televisions, video machines, etc) the annual GHG reductions will be reported for the years 2020 and 2030. The present value of the cumulative incremental costs and the undiscounted cumulative emission reductions will be reported for the entire period from the beginning of the phase-in up through 2030.

Start and End Years for Analysis

The beginning of the analysis period for which GHG reduction benefits and incremental costs will be calculated is the year 2011, considered to be the earliest year for which GHG mitigation options could be introduced in NY. The end of the analysis period is 2030.

Transparency

Data sources, methods, implementation mechanisms, key assumptions, and key uncertainties will be documented and supported by references to provide transparency on how the key analytical outputs for each policy option were developed and applied. Information provided by the state agencies and project participants will be used to ensure best available data sources, methods, and key assumptions using their expertise and knowledge to address specific issues in New York State. Modifications will be made through facilitated discussions.

Key Analytical Outputs and Metrics

GHG emission reductions

Net GHG reduction potential in physical units of million metric tons (MMt) of carbon dioxide equivalent (CO₂e) will be estimated for each quantifiable policy for each target year, 2020 and 2030, and cumulative reductions through 2030. As noted earlier, full fuel cycle or life cycle analysis will be used to evaluate net energy (and emissions) performance of policy options, as appropriate. Net analysis of the effects of carbon sequestration will be conducted where applicable. (See the section on “GHG Emissions and Emission Reductions” for additional details.)

Costs

Net capital, operating and maintenance (O&M), and fuel costs will be estimated for each of the policy options that are determined quantifiable. Costs will be discounted as a multi-year stream of net costs to arrive at the “net present value cost” associated with implementing new technologies and best practices. It is proposed that costs be discounted for all options in constant 2005 dollars using a 5 percent annual real discount rate. The nominal discount rate will be calculated by adding the projected inflation rate over the analysis period.⁴ Capital investments

⁴The inflation rate for the analysis period is assumed to be 2.2%, subject to approval by the Integration Advisory Panel and Climate Action Council. Capital and other costs reported in nominal dollars will be converted to 2005\$ using the inflation rate for the NY state region as reported by the Bureau of Labor Statistics (<http://www.bls.gov/ro2/news.htm>)

will be represented in terms of annualized or amortized costs over the project period. Discounting will begin in this initial year of the analysis period (i.e., assumes investment occurs in the beginning of the year). Policies that result in energy savings relative to the baseline technology or practice may result in a cost savings (recorded as a negative value). As noted above, the discount rate will be kept constant for the evaluation of all GHG mitigation options - risk and uncertainty will be accounted for by calculating option-specific cash flows that account for policy, practice, or technology differences.

Cost-effectiveness

The cost effectiveness for each quantified policy will be calculated by dividing the present value cost by the cumulative (undiscounted) reduction in metric tons of GHG emissions. Because monetized dollar value of GHG reduction benefits are not available, physical benefits will be used instead, measured as dollars per metric ton of carbon dioxide equivalent (tCO_{2e}) or “cost effectiveness” evaluation. Both positive costs and cost savings (negative value) will be estimated as a part of compliance cost. When combined with GHG impact assessments, the results of these cost estimates will be aggregated into a sectoral summary table and sector and economy-wide stepwise marginal cost curves.

Direct vs. indirect effects

Socio economic impact of policy options and scenarios will include direct effects, but will not include indirect and distributional effects. Direct effects are those borne or created by the entities, households or populations subject to the policy or implementing the new policies; for example, a policy encouraging the purchase of advanced technology vehicles would include an evaluation of the incremental cost of the vehicles, and the savings on fuel cost and associated GHG emissions. Indirect effects are defined as those borne or created by the entities, households or populations other than those implementing the policy recommendation; in the above example, this could be the number of jobs created/lost by the alternative GHG mitigation investments, or the reduction in ambient air pollution concentrations. Distributional effects refer to the extent to which a GHG mitigation policy design may result in disproportionate impacts on different regions, sectors, communities, or households. Some examples of direct and indirect net costs and benefits metrics are included in Annex 1 at the end of this memo for purposes of illustration.

End effects

For GHG mitigation options whose lifetimes extend beyond the end of the analysis period (i.e., beyond 2030), only costs and benefits that fall within the analysis period will be fully included in the analytical results. For long-lived investments (e.g., public transport infrastructure, nuclear power plants) whose costs and benefits extend beyond 2030, GHG reductions up through 2050 will be quantified in order to be able to offer a direct comparison with the 80 by 50 goal. In order to make this comparison, sectoral business-as-usual GHG projections will be estimated for the 2031-2050 period using simple extrapolation techniques, except for technologies that mature at the end of the study period or decline in effectiveness discontinuously after 2030. Incremental costs in the 2031-2050 period will be accounted for qualitatively in the write-up of results.

Non-GHG (external) impacts and costs

Environmental co-benefits such as reductions in criteria air pollutants which in turn would lead to reduced public health impacts from productive activities in New York are to be analyzed separately. Qualitatively, CCS will document measures that are expected to have other non-GHG impacts, including water quality, water use, solid waste reduction, and environmental justice issues and will provide information as available and needed to support quantification of these impacts.

Biomass supply & demand

Within the AFW Common Assumptions memorandum, estimates of biomass supply will be prepared. Estimates are provided for all known feedstocks, including municipal solid waste fiber, in units of dry tons and million British Thermal Units (MMBtu). During the course of GHG quantification, CCS will maintain a spreadsheet to be used by the team to track demand by each mitigation approach (e.g., biomass to energy, liquid biofuels production).

Uncertainty / Sensitivity Analysis

Key uncertainties and feasibility issues will be identified and discussed qualitatively. For instance, the certainty of energy price forecasts and technology change rates may vary significantly across certain sectors and actions. Characterization of the source and potential magnitude of uncertainty will be useful to policymakers as they make future policy decisions. To the extent that data are available and time and resources allow, a quantitative assessment of uncertainty or certain parameter sensitivities will be included in the analysis of policy options by conducting sensitivity analysis.

GHG Emissions and Emission Reductions

New York State GHG Emissions Inventory and Forecast

To estimate statewide impacts associated with potential policies, information on current and future energy use and the extent of application (penetration) of both baseline and policy options will be needed. Working with CCS, NYSERDA has prepared a comprehensive GHG emissions inventory for 1990 through 2008 and a forecast to 2030 for all emission source sectors. The emissions inventory and forecast has been prepared at the state-level representing a planning inventory rather than a compliance inventory. Forecast data used to support the development of New York's 2009 State Energy Plan were used to revise the forecast of energy demand and emissions. Historical fuel use data used in preparing the inventory are provided in a separate publication; these data rely on data published by the U.S. Energy Information Administration.⁵

Calculation of Emission Reductions for Policy Options

Emission reductions for individual policies will be estimated incremental to baseline emissions based on the change (reduction) in emissions activity (e.g., physical energy units) or as a percentage reduction in emissions activity (e.g., physical energy units or emissions) depending

⁵ Patterns and Trends, New York State Energy Profiles: 1993-2008, prepared by New York State Energy Research and Development Authority Energy Analysis Program.

on the availability of data. This information will be needed to support the cost-effectiveness calculation for each policy option.

Fuel- and pollutant-specific emission factors will be used to convert physical units of emissions activity to emissions. The emission factors will be based on those that NYSERDA uses to prepare the GHG emissions inventory and forecast for New York State, and are provided in the Sector-specific “Common Assumptions” memoranda. For fuel combustion sources, fuel-specific oxidation factors will be used with emission factors to estimate emissions. Fuel combustion oxidation factors refer to the percentage of fuel that is fully oxidized during the combustion process. Table E-2 provides the oxidation factors to be used for this analysis; these factors are based on those used in the EPA’s most recent GHG inventory for the U.S.⁶

Table E-2. Fuel Combustion Oxidation Factors

Fuel	Oxidation Factor
Coal	0.990
Natural Gas and LPG	0.995
Distillate and Residual Oil	0.990
Municipal Solid Waste	0.980

Energy Conversion Factors

Energy conversion factors refer to the energy density of fuels used in New York. These factors are provided in the Sector-specific “Common Assumptions” memoranda. Energy conversion factors obtained from NYSERDA will be used for this project. Otherwise, default energy conversion factors will be taken from Table Y-2 (Conversion Factors to Energy Units (Heat Equivalents)) of Appendix Y in the EPA’s most recent GHG Inventory for the U.S.⁷

Cost Analysis Methods

Cost Effectiveness

Because the monetized dollar value of GHG reduction benefits are not available, physical benefits are used instead, measured as dollars per tCO₂e (cost or savings per metric ton) or “cost effectiveness.” Both positive costs and cost savings (negative values) are estimated as a part of mitigation cost. When combined with GHG impact assessments, the results of these cost estimates will be aggregated into a stepwise marginal cost curve that can be broken down by sector or subsector as needed, as well as sub state region for key measures.

The net cost of saved carbon of a proposed policy option is calculated by dividing the cumulative future streams of incremental costs, discounted back to the present time, by the cumulative

⁶ U.S. EPA, April 2010. Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2008. Available at: <http://epa.gov/climatechange/emissions/usinventoryreport.html>.

⁷ Available at: [http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJTCL/\\$File/2003-final-inventory_annex_y.pdf](http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJTCL/$File/2003-final-inventory_annex_y.pdf).

undiscounted net CO₂e reductions achieved by the technology or best practice. Mathematically, the equation to be used is as follows:

$$CSC = \frac{\sum_{t=0}^n \left\{ \frac{((LC_m - LC_r) * A_t)}{(1 + D_r)^t} \right\}}{\sum_{t=0}^n (CO_{2e_r} - CO_{2e_m})}$$

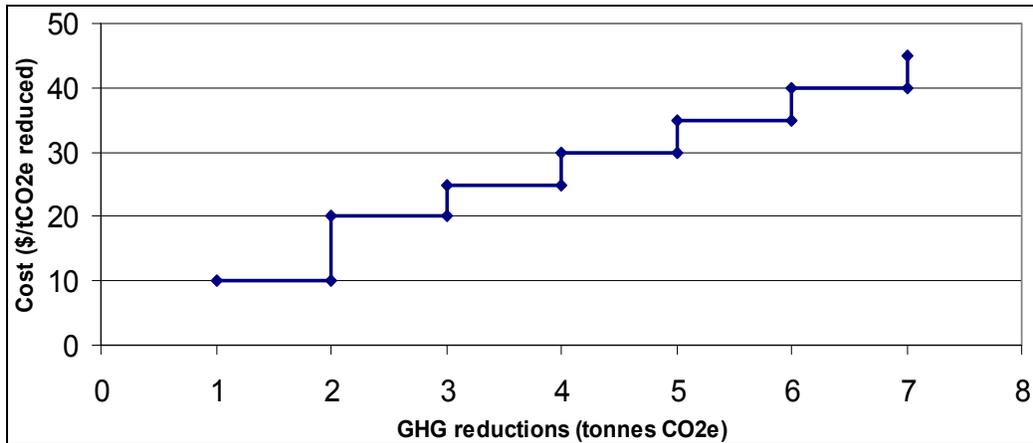
where:

- CSC = Cost of saved carbon (or cost-effectiveness) of a technology or best practice, \$/tCO₂e avoided
- LC_m = Levelized cost of a technology or best practice, \$/activity unit
- LC_r = Levelized cost of the baseline or reference technology or best practice, \$/activity unit
- A = Amount of activity affected by the technology or best practice in year t, activity unit
- D_r = Real discount rate, dimensionless
- CO_{2e_r} = CO₂e emissions associated with the baseline or reference technology or best practice in year t, metric tons CO₂e
- CO_{2e_m} = CO₂e emissions associated with a technology or best practice in year t, metric tons CO₂e
- t = year in the evaluation period (0 ≤ t ≤ 40)

Activity units refer to a unit indicator of GHG emissions activity for a policy option. The activity units will vary depending on the Sector and within each sector the individual option. The activity units are used to normalize data for comparison of the policy option to the baseline. For example, for the Power Supply and Delivery sector, MWh of gross electricity generation could be used as the activity unit such that dollars per megawatt-hour (\$/MWh) would be used as the activity unit for the “LC_m” and “LC_r” terms and MWh would be used as the activity unit for the cost terms in the equation.

The results of the analyses will be used to develop a GHG abatement cost curve which will rank each technology or best practice in the order of its cost effectiveness for reducing a metric ton of CO₂e emissions. This ranking will be represented in the form of a curve that is similar conceptually to Figure E-1. Each point on this curve represents the cost-effectiveness of a given policy option relative to its contribution to reductions from the baseline, expressed as a percentage. The points on the curve appear sequentially, from most cost-effective in the lower left area of the curve, to the least cost-effective options located higher in the cost curve in the upper right area.

Figure E-1. Example Cost Curve



The costs of each policy option that will be evaluated will be levelized and converted into dollars per activity unit. The cost components to be considered include capital, fixed O&M, variable O&M, and fuel costs. Other sector-specific costs (e.g., transmission of electricity) will be included as applicable to each sector.

The levelization calculation is similar to amortization and its purpose is to develop a level stream of equal dollar payments that lasts for a fixed period of time. The levelization formula to be used in the analysis is as follows:

$$LC = \frac{[PV * D_r * (1 + D_r)^t]}{((1 + D_r)^t) - 1}$$

where:

- LC = Levelized cost of the a technology or best practice, \$/activity unit
- PV = Present value of discounted cost stream
- D_r = Real discount rate, dimensionless
- t = Levelization period, or number of years over which payments are to be made

There are several parameters that will be used in the levelization process. Some are technology-specific (e.g., plant lifetime, capacity factor), others are state-specific (e.g., state income tax rate), others are market-driven (cost of capital), while others are a matter of policy (e.g., real discount rate).

Capital Costs

Capital costs represent the material, equipment, labor, and other costs associated with the implementation of a policy option relative to the baseline or reference technology or practice. For policy options that require a capital investment, these costs will be annualized using a fixed charge rate (FCR), a factor that is the sum of the cost of capital (equals the cost of debt plus the cost of equity), taxes, and depreciation. Differences between public/private financing costs will be captured through sector-specific assumptions regarding equity/debt fractions and depreciation schedules. For long-term capital investments that extend beyond 2030, the investment will be

annualized over its operational lifetime; only costs incurred within the 2011-2030 analysis period will be fully included in the presentation of quantitative results.

Annual O&M Costs

O&M costs refer to labor, equipment, and fuel costs related to annual operation and maintenance of policy measures and are differentiated into annual expenditures (i.e., variable O&M) and fixed expenditures (i.e., fixed O&M). Variable O&M estimates are provided in activity units over the full period of operation of the technology. O&M costs are described and included in the LCC when there is a differential between the baseline technology and the GHG-reducing alternative.

Forecast of Fuel Demand, Prices, and Costs

Fuel demand and price forecasts will be based on the information developed for New York's State Energy Plan. This information will include fuel demand and price forecasts for 2011 through 2030 by sector and fuel type in both physical (e.g., gallons, cubic feet, barrels) and energy (e.g., British thermal units [Btu]) units. The sectors covered include electricity generation; residential, commercial/institutional, and industrial; and transportation. The fuels covered include natural gas, petroleum (motor gasoline, kerosene, liquefied petroleum gas, distillate and residual oil), and coal, nuclear fuel, and renewable fuels (biomass and landfill gas). For the purpose of developing abatement cost curves, the fuel demand and price forecasts developed by NYSERDA, NYISO, and other sources will be used for all sectors. Fuel costs (including avoided fuel costs) will be calculated using this information along with fuel consumption estimates developed for each technology or best practice.

Avoided Electricity Generation Costs

For policy options in the RCI, agriculture, and waste sectors that reduce electricity demand, the amount and cost of electricity avoided will be estimated. Information on avoided electricity costs will reflect the consensus of the project research team, NYSERDA, and the Climate Action Council.

Interactions with the Regional Greenhouse Gas Initiative (RGGI)

RGGI is a ten-state agreement to reduce GHG emissions through a cap and trade system focused only on the supply of electric power. States within RGGI have negotiated a regional CO₂ emission cap for the power sector of 188 million short tons per year through 2014 (cap of 64 million short tons for NY), with the cap being strengthened by 2.5 percent per year over the period 2015 through 2018. The energy modeling undertaken to develop New York's State Energy Plan fully incorporates the RGGI program in the reference case forecast. Hence, all power sector GHG mitigation policies to be analyzed are considered incremental to the RGGI program since they will achieve greater GHG emissions than the RGGI program. In addition, a more stringent RGGI program itself will be analyzed as part of the PSD-6 option.

Documentation

Documentation of the work completed for each policy option for each sector will be completed in a template format that addresses the items listed below (among others) to ensure consistency for comparison of information and also assist with identifying data gaps that will be addressed.

Work Group Sector

Name of policy option

Policy Description

Policy Design (Goals and Timing for implementation and parties involved or affected by implementation of the policy.)

Implementation Mechanisms

Quantification: Estimated GHG Savings and Costs per MtCO₂e (GHG reduction potential in 2020 and 2030, Cumulative GHG reduction potential, net cost, data sources, and quantification methods)

Key Assumptions and Uncertainties

Co-Benefits and External Costs (qualitative discussion)

Annex 1: Examples of Direct/Indirect Net Cost and Benefit Metrics

Note: These examples are meant to be illustrative and are not necessarily comprehensive.

A. Direct Costs and/or Savings

Transportation and Land Use (TLU) Sector

- Incremental cost of more efficient vehicles net of fuel savings, net of fuel savings.
- Incremental cost of implementing Smart Growth programs, net of saved infrastructure and service costs plus fuel savings and reduced consumption.
- Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure and service costs (e.g., roads)
- Incremental cost of alternative fuel, net of any change in maintenance costs
- Net effects of carbon sequestration from land use measures

Residential, Commercial, and Industrial (RCI) Sectors

- Net capital costs or savings (or incremental costs or savings relative to standard practice) of improved buildings, appliances, equipment (cost of higher-efficiency refrigerator versus refrigerator of similar features that meets standards)
- Net operation and maintenance (O&M) costs or savings (relative to standard practice) of improved buildings, appliances, equipment, including avoided/extra labor costs for maintenance (less changing of compact fluorescent light (CFL) or light-emitting diode (LED) bulbs in lamps relative to incandescent)
- Net fuel (gas, electricity, biomass, etc.) costs (typically as avoided costs from a societal perspective)
- Cost/value of net water use/savings
- Cost/value of net materials use/savings (for example, raw materials savings via recycling, or lower/higher cost of low-global warming potential (GWP) refrigerants)
- Direct improved productivity as a result of industrial measures (measured as change in cost per unit output, for example, for an energy/GHG-saving improvement that also speeds up a production line or results in higher product yield)

Energy Supply (ES) Sector

- Net capital costs or savings (or incremental costs or savings relative to reference case technologies) of renewables or other advanced technologies resulting from policies
- Net O&M costs or savings (relative to reference case technologies) renewables or other advanced technologies resulting from policies
- Avoided or net fuel savings (gas, coal, biomass, etc.) of renewables or other advanced technologies relative to reference case technologies resulting from policies
- Total system costs (net capital + net O&M + avoided/net fuel savings + net imports/exports + net transmission and distribution (T&D) costs) relative to reference case total system costs

Agriculture, Forestry, and Waste Management (AFW) Sectors

- Net capital costs or savings (or incremental costs relative to standard practice) of facilities or equipment (e.g., manure digesters and associated infrastructure, generator; ethanol production facility)
- Net O&M costs or savings (relative to standard practice) of equipment or facilities
- Net fuel (gas, electricity, biomass, etc.) costs or avoided costs
- Cost/value of net water use/savings
- Cost/value of carbon sequestration from land use measures
- Reduced VMT and fuel consumption associated with land use conversions (e.g., as a result of forest/rangeland/cropland protection policies)

B. Indirect Costs and/or Savings across All Sectors

- Net value of employment and income impacts, including differential impacts by socio economic category
- Re-spending effects on the economy from financial savings
- Net changes in the prices of goods and services in the region
- Health benefits of reduced air and water pollution
- Ecosystem benefits of reduced air and water pollution
- Value of quality-of-life improvements
- Value of improved road and community safety
- Energy security
- Net embodied energy of materials used in buildings, appliances, equipment, relative to standard practice
- Improved productivity as a result of an improved working environment, such as improved office productivity through improved lighting (though the inclusion of this as indirect might be argued in some cases)
- Higher cost of electricity in the region

AFW Common Assumptions Memorandum - Draft

To: NYS Climate Action Plan Agriculture, Forestry, and Waste Management
Technical Workgroup

From: Steve Roe and Brad Strode

CC: Tom Peterson, Jeff Wennberg, Randy Strait, Sandra Meier

Subject: Assumptions used in the quantification of options for the AFW Technical Work
Group

Date: July 12, 2010

This memorandum summarizes methods, data sources, and key assumptions to be used to estimate the GHG reductions and costs for AFW sector mitigation options. The information presented here builds on the general approaches and data sources laid out in the overview quantification memorandum covering all sectors (including common emission factors, cost assumptions, etc.).

Quantifying reductions of GHG (particularly future reductions) is an inherently complex process and assumptions are important inputs into the quantification methodologies and models used to estimate mitigation costs and benefits. Models are representations of reality, and require the best available data on likely futures. An emphasis should be placed on using assumptions that are based on the best available data using local or regional data (when available) rather than national level data.

CCS has developed estimates of GHG emissions and forecasts for the AFW sector to supplement the inventory prepared by DEC (which primarily covered combustion sources). These inventory and forecast data are needed to support the development of mitigation cost curves and to provide context to the selection of mitigation priorities. For emission inventories previously developed by CCS, the only sector for which consumption-based emissions data are provided is the electricity consumption sector. Other sectors of the inventory tend to only include GHG emissions that occur within the state as a result of energy consumption or other GHG emission process (e.g., methane from landfilled waste). For example, for fuel combustion in the RCI and Transportation sectors, only the emissions associated with fuel combustion are provided, not those associated with the extraction, transport, processing, and distribution of each fuel. Similarly, for waste management, only emissions associated with waste management processes in New York would be included in the inventory (e.g., landfilling, waste combustion), not those associated with production and transportation of the initial packaging or product that became a component of the solid waste stream. In addition, emissions from the management of New York waste that is exported out of state are not included.

For some mitigation options, fuel cycle emission reductions can be estimated, and it should be recognized that there are likely to be at least a portion of emission reductions that occur out-of-state as a result of in-state mitigation actions:

- Fossil fuel consumption: inventory estimates are based only on the GHG emissions associated with the combustion of each fuel; fuel cycle emission reductions are estimated using GHGs from combustion plus the embedded GHGs from extraction, transportation, processing, and distribution;
- Solid waste management: landfill methane emissions or total GHG emissions are associated only with waste combustion and decomposition for in-state managed waste; fuel cycle emission reductions include the landfill/waste combustion emissions plus those associated with production and distribution of the initial packaging or product (e.g., net difference of use of virgin materials versus recycled materials). Also, emission reductions that occur out of state from reductions in exported waste should be captured in the analysis; and,
- Biofuels consumption: for fossil fuel displacement benefits, the inventory includes only GHGs from fossil fuel combustion; fuel cycle emission reductions are estimated using the fuel cycle gasoline/diesel emission factors compared to fuel cycle biofuel emission factors (captures total GHGs from fuel production, processing, and distribution).

For the AFW Technical Work Group, CCS will estimate the in-state GHG reductions for each mitigation option selected for analysis. Where data and methods are available to do so, CCS will also specify the fuel cycle emission reductions, reporting these reductions as co-benefits. This method is based on the most recent guidance from Climate Action Plan project leaders. CCS also strives to estimate fuel cycle reductions for GHG mitigation in the other work group areas (Areas); so, it is important for the Climate Action Council to understand the ramifications of this (e.g., measurement of fuel cycle GHG reductions against a GHG forecast that is not based on fuel cycle emission estimates).

Common assumptions used in the development of mitigation options in other sectors (especially energy supply and transportation) are also used for the quantification of many AFW mitigation policy options. These could include future costs of fossil fuels, electricity consumption-based emission factors, costs for new electricity generation, and future gasoline and diesel consumption. In the discussion of common assumptions for the AFW sector in the sections below, CCS also notes instances where the AFW analysis will borrow common assumptions from other sectors. These common assumptions have been documented in the overview quantification memorandum, as well as the Area-specific memos (e.g., Power Supply and Delivery (PSD), Transportation and Land Use (TLU)).

Quantification Process

The analysis includes spreadsheet modeling techniques in which assumptions are transparent and readily accessible for review. The assumptions delineated in the following document are for the quantification of the policy options developed by the AFW Technical Work Group. This quantification of costs and CO₂ reductions entails the following steps:

- Develop stand-alone GHG reduction and cost estimates for each quantifiable option;
- Once completed, the stand alone options will be adjusted to reflect existing actions;
- To assess the AFW emission reductions without double-counting, it is necessary to consider overlaps and interactions within the AFW policies and measures;

- Options will be also be modified to reflect overlaps between AFW options and other Technical Work Group options. Potential interactions occur between AFW policies and measures that deploy renewable energy with PSD; Residential, Commercial, and Industrial (RCI); and TLU mitigation measures.

Common Methods, Assumptions, and Data Sources for GHG Mitigation

Forestry - Afforestation/Reforestation: Assumed Sequestration Rates and Costs

Carbon sequestered by afforestation activities is assumed to occur at the same rate as carbon sequestration in average New York state forests. Average carbon storage rates were determined based on USFS GTR-NE-343,⁸ assuming afforestation activity with a forest type distribution of 70% maple-beech-birch, 15% oak-hickory, and 15% white-red-jack pine. This distribution is reflective of the average forest composition in New York and is based on the major forest types identified by USFS.⁹ A 45-year project period is assumed, such that the rate of forest carbon sequestration under afforestation projects for an average acre in New York was estimated at 1.1 metric tons of carbon (tC)/acre/year (see Table E-3).

Table E-3. Average carbon sequestration rate for afforestation projects

Forest type	Assumed Distribution	tC/acre (0 year)	tC/acre (45 year)	tC/acre/year
Maple-beech-birch	70%	0.8	50.6	1.1
Oak-hickory	15%	0.8	56.2	1.2
White-red-jack pine	15%	0.8	37.1	0.8
Weighted Average				1.1

tC/acre = metric tons of carbon per acre. Excludes soil organic carbon pool due to the uncertainty in those estimates.

For reforestation projects, CCS would also use data from the same publication to derive an average sequestration rate. Reforestation refers to projects occurring on lands that had recently been under forest cover (such as planting projects following clear-cut harvesting).

Estimated per acre costs for afforestation in New York were obtained from Walker et al. 2007,¹⁰ who surveyed state foresters, regional foresters, or other foresters and related specialists in the USFS, universities, and forest companies, and reported the results on a state-by-state basis. Costs include site preparation, labor, seedlings, and herbivore protection (Walker et al. 2007). Average per-acre afforestation costs in New York were estimated to be \$550 for both hardwoods and softwoods. This is a one-time cost incurred in the year of planting.

⁸ J.E. Smith, L.S. Heath, K.E. Skog, and R.A. Birdsey. 2006. Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. USDA USFS Northeastern Research Station. General Technical Report GTR-NE-343. (This document is also published as part of the US DOE 1605(b) Voluntary GHG Reporting Program). See http://nrs.fs.fed.us/pubs/gtr/ne_gtr343.pdf.

⁹ Carbon in United States Forests and Wood Products, 1987-1997: State-by-State Estimates by Richard A. Birdsey & George M. Lewis. (available at <http://www.fs.fed.us/ne/global/pubs/books/epa/states/NY.htm>)

¹⁰ S. Walker, S. Grimland, J. Winsten, and S. Brown. 2007. Terrestrial carbon sequestration in the Northeast: opportunities and costs part 3A: opportunities for improving carbon storage through afforestation of agricultural lands. Report to The Nature Conservancy Conservation Partnership Agreement by Winrock International, prepared with the support of the US DOE under Award No. DE-FC26-01NT41151.

Agriculture - Land Value and Conservation Easement Costs

If better information on conservation easement costs is not available for agricultural lands (e.g., historical in-state costs paid for conservation easements), the mitigation cost quantification will assume Conservation Reserve Program (CRP) annual payments as a proxy for easement costs.

CRP land annual payments for New York were projected across the mitigation period based on historical payments (see Table E-4), and is escalated to account for increased land value across the period.¹¹

Table E-4. 2007 and projected CRP payments¹²

Year	CRP Enrollment (Acres)	Annual Payment (Thousand\$)	Annual Payment (\$/acre)	Annual Payment (revised to 2005\$/acre)
2007	66,544	\$4,863	\$73.08	\$66.29
2008	67,832	\$5,040	\$74.30	\$67.39
2009	69,144	\$5,223	\$75.54	\$68.52
2010	70,482	\$5,414	\$76.81	\$69.67
2011	71,846	\$5,611	\$78.09	\$70.83
2012	73,236	\$5,815	\$79.40	\$72.02
2013	74,654	\$6,027	\$80.73	\$73.22
2014	76,098	\$6,246	\$82.08	\$74.45
2015	77,571	\$6,473	\$83.45	\$75.69
2016	79,072	\$6,709	\$84.85	\$76.96
2017	80,602	\$6,953	\$86.27	\$78.25
2018	82,162	\$7,206	\$87.71	\$79.56
2019	83,752	\$7,469	\$89.18	\$80.89
2020	85,372	\$7,741	\$90.67	\$82.24
2021	87,024	\$8,022	\$92.19	\$83.61
2022	88,708	\$8,314	\$93.73	\$85.01
2023	90,425	\$8,617	\$95.30	\$86.44
2024	92,175	\$8,931	\$96.89	\$87.88
2025	93,959	\$9,256	\$98.51	\$89.35
2026	95,777	\$9,593	\$100.16	\$90.85
2027	97,630	\$9,942	\$101.83	\$92.37
2028	99,519	\$10,304	\$103.54	\$93.91
2029	101,445	\$10,679	\$105.27	\$95.48
2030	103,408	\$11,068	\$107.03	\$97.08

¹¹ Under the Conservation Reserve Program (CRP), the USDA establishes contracts with agricultural producers to retire environmentally sensitive land. During the 10- to 15-year CRP contract period, farmland is converted to grass, trees, wildlife cover, or other conservation uses providing environmental benefits, including improvement of surface water quality, creation of wildlife habitat, preservation of soil productivity, protection of groundwater quality, and reduction of offsite wind erosion damages. The program also assists farmers by providing a dependable source of income. See http://www.fsa.usda.gov/Internet/FSA_File/annual_consv_2007.pdf.

¹² See http://www.fsa.usda.gov/Internet/FSA_File/annual_consv_2007.pdf

Agriculture - Tilling Practices

The reduction in fossil diesel fuel use associated with changing land use from intensive agriculture to alternative land use or practices is estimated at 3.5 gallons/acre.¹³ The fuel cycle fossil diesel GHG emission factor is 12.3 tCO₂e/1,000 gallons.¹⁴ This will be revised as needed to reflect the value assumed in the TLU section of this memorandum (i.e., based on the NYGREET model).

Agriculture – Fertilizer Application GHG Emissions and Costs

The fertilizer cost information provided in Table E-5 is taken from U.S. Department of Agriculture, Economic Research Service’s U.S. fertilizer use and price information (see <http://www.ers.usda.gov/Data/fertilizeruse/>). A weighted price of applied nitrogen was derived from this information using the most recent data available from United States Department of Agriculture (USDA).

Table E-5. Average US price of common nitrogen fertilizers

Month/Year	Average U.S. farm prices of selected fertilizers				
	Anhydrous ammonia	Nitrogen solutions 30%	Urea 45-46% nitrogen	Ammonium nitrate	Ammonium Sulfate
Apr 2007	<i>\$/short ton</i>				
	523	277	453	382	288
	<i>N content (%)</i>				
	82	30	46	34	21
	<i>\$/short ton nitrogen</i>				
	638	923	985	1,124	1,371
2006	<i>US Consumption</i>				
	3,821,891	10,104,319	5,369,913	963,710	1,218,964
2006-2007	<i>Weighted \$/short ton nitrogen</i>				
	862				

To predict fertilizer prices in the future, the historical growth rate for fertilizer prices was used. Nominal (unadjusted for inflation) growth in fertilizer prices between 1990 and 2007 averaged 7.96% growth.¹⁵ However, when this figure is adjusted for inflation, this growth rate is significantly less dramatic. A growth rate for fertilizer price was used because fertilizer prices can fluctuate dramatically, and therefore holding these prices constant (in real dollars) did not

¹³ Reduction associated with less intensive land use (e.g., fewer passes). The estimate is based on conservation tillage compared with conventional tillage, at <http://www.conservationinformation.org/Core4Brochures/CTBrochure.pdf>, accessed May 2008.

¹⁴ Fuel-cycle emissions factor for fossil diesel from J. Hill et al., "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," Proceedings of the National Academy of Sciences, 103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life-cycle impacts. See <http://www.pnas.org/cgi/content/full/103/30/11099>.

¹⁵ USDA ERS. Table 7. “Average U.S. farm prices of selected fertilizers.” <http://www.ers.usda.gov/Data/FertilizerUse/> Accessed 10/7/08.

seem an accurate estimate. Another option would be to tie fertilizer prices to natural gas prices, because natural gas costs make up 70 percent of all fertilizer production costs.¹⁶ However, given the uncertainty involved in estimating natural gas prices, as well as the potential impact of price fluctuations (which will cause fertilizer prices to rise in the face of uncertainty), this method was not used.

The avoided fuel cycle GHG emissions (i.e., emissions associated with the production, transport, and energy consumption during application) were taken from Wood and Cowie.¹⁷ The estimate provided for the U.S. (taken from West and Marland, 2001¹⁸) was 858 grams (g) CO₂e per kilogram of nitrogen (kgN).¹⁹ In addition to the avoided fuel cycle emissions, land application nitrous oxide emissions also need to be accounted for. Traditionally, CCS has used information generated by the U.S. EPA's State Inventory Tool. In the absence of alternative data, CCS will use this tool to determine nitrous oxide emission estimates and the assumed emissions factor for nitrogen applied (i.e., X kg CO₂e / kgN applied). Combining these two emission factors provides a total emissions factor per kilogram of nitrogen applied.

Waste Management - Recycling Capital Costs

For other states, CCS has used a value of \$129/household for recycling program capital costs, based on an analysis in Vermont.²⁰ CCS will research the availability of capital cost data specific to New York City and the rest of the state to determine whether more state-specific data are available.

Waste Management – Landfill and Compost Tipping Fees and Transportation Cost

Diverting waste from landfills can reduce costs by avoiding tipping fees. The average landfill tipping fee assumed to represent New York State is \$45/ton.²¹ Additional transportation and transfer costs are assumed to add \$55 per ton to the total disposal cost. CCS will consult the AFW Technical Work Group regarding the potential growth rate of tipping fees. Tipping fees for composting facilities and recycling haulers must also be considered. Tipping fees for composting facilities can range from \$15/ton to \$50/ton depending on location and type of material being received. For other states, CCS has assumed a tip fee to recycling haulers of \$10/ton.²² It is to be

¹⁶ Huang, Wen-yuan. "Impact of Rising Natural Gas Prices on U.S. Ammonia Supply." USDA. August 2007. <http://www.ers.usda.gov/Publications/WRS0702/> Accessed 10/7/08.

¹⁷ Sam Wood and Annette Cowie (2004) *A Review of Greenhouse Gas Emission Factors for Fertilizer Production* Research and Development Division, State Forests of New South Wales, Cooperative Research Centre for Greenhouse Accounting.

¹⁸ West, T. O. and Marland, G. 2001. A Synthesis of Carbon Sequestration, Carbon Emissions and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States. *Agriculture, Ecosystems and Environment* 1812, 1-16.

¹⁹ These emission factors provide an estimate of the typical fuel cycle GHG emissions (including resource extraction, the transport of raw materials and products, and the fertilizer production processes) per unit weight of fertilizer produced (i.e., gCO₂e/kg fertilizer).

²⁰ P. Calabrese, Cassella Waste Management, personal communication, S. Roe, CCS, 2007.

²¹ Personal communication from Resa Dimino of NYS DEC. Provided to B. Strode (CCS) via e-mail.

²² J. Ketchum, Waste Management, personal communication with S. Roe, CCS, November 20, 2007.

assumed that recycling and composting facilities are closer to the point of generation and an incremental increase in these activities will not lead to a change in transportation costs.

Waste Management - Value of Recycled Materials

Current US market prices for recycled materials are available from the RecycleNet.²³ This service reports current prices for materials such as scrap metal and scrap plastic, as well as, curbside recyclables, including newspapers, office paper, loose waste paper, polyethylene terephthalate (PET), high-density polyethylene (HDPE), aluminum, steel cans, and glass. However, due to the large scale of variability in market prices for recycled material seen in recent years, the value of recycled materials is uncertain. DEC has indicated that NYC estimates total recycling revenues at \$7 to \$12 million per year.

Waste Management - EPA Waste Management Software Tools

EPA has several models that may be used to estimate GHG impacts or costs of waste management mitigation options.²⁴ The Landfill Gas Energy Cost Model (LFGcost-Web) estimates costs for landfill gas energy projects. The Waste Reduction Model (WARM) estimates GHG emission reductions from different waste management practices. The Landfill Gas Emissions Model (LandGEM) is a tool for estimating emissions from MSW landfills.

All AFW Sectors - Energy Consumption Emission Factors

Both fuel cycle and standard (fuel combustion) emission factors for energy consumption will be taken from the PSD and TLU quantification methods memoranda, as applicable (e.g., transportation fuels will be taken from the TLU section).

All AFW Sectors - Fuel Prices

As with emission factors above, assumptions for fuel prices will be taken from the applicable ES or TLU quantification methods memoranda.

All AFW Sectors - Electricity Capital Costs and Capacity Factors

Where these estimates are needed, they will also be taken from the PSD quantification methods memorandum.

All AFW Sectors - Renewable Incentives

Inclusion of the federal production tax credit (PTC) in the levelized cost estimates for renewables in the mitigation options analyzed needs to be considered. The federal Renewable Electricity Production Tax Credit has been around in some form since 1992 but seems to always be about to expire (currently December, 2012 for wind and December, 2013 for other renewable sources). The existing incentive for closed-loop biomass is 2.0¢/kWh. Electricity from open-loop biomass, landfill gas, and municipal solid waste resources receives a 1.0¢/kWh credit.

²³ RecycleNet Spot Market Pricing, <http://www.scrapindex.com/index.html>.

²⁴ EPA Waste Management Tools, <http://www.epa.gov/cleanenergy/energy-programs/state-and-local/by-topic/waste.html>.

PSD Common Assumptions Memorandum - Draft

To: NYS Power Supply and Delivery Technical Workgroup
From: Bill Dougherty and Jeff Wennberg
CC: Tom Peterson, Randy Strait, Jared Snyder, Carl Mas
Subject: Assumptions used in the quantification of options for the PSD Technical Work Group
Date: August 4, 2010

This memo outlines proposed data sources used to quantify the greenhouse gas (GHG) impacts and costs for those PSD Technical Work Group policy options that are considered amenable to quantification. The memo will be reviewed in an upcoming Technical Work Group call so that comments on the assumptions may be made and alternative data sources recommended for Technical Work Group approval. Any changes to this memo will be incorporated and the revised memo will be used as documentation for the modeling results.

The scope of this memo only covers the major assumptions directly related to the quantification of the PSD policy options. Recall that the emissions reductions and costs in the quantification of the policy options occur against the backdrop of the GHG forecast that includes recent state actions. The effects of the policy options are therefore incremental to the activity projected under the forecast. The assumptions embedded in the New York Inventory and Forecast were reviewed during a PSD Technical Work Group call held early in the process.

Quantification Process

The analysis includes spreadsheet modeling techniques in which assumptions are transparent and readily accessible for review. The assumptions delineated in the following document are for the quantification of the priority policy options developed by the PSD Technical Work Group.

This quantification of incremental costs from the introduction of GHG mitigation options and their corresponding CO₂e reductions entails the following steps:

- Establish the levelized cost and GHG emission characteristics of the appropriate power supply resource(s) in the Baseline GHG forecast that would be displaced by the technologies in each priority GHG mitigation policy.
- Develop stand-alone levelized cost estimates for each technology included as part of a quantifiable policy option. Some policies might require that CCS evaluate different scenarios (e.g., renewable resource mix). This will be approached on a case-by-case basis through Technical Work Group-generated design of sensitivity analyses.
- Estimate the incremental costs and GHG reductions for each stand-alone policy.

- After the stand-alone analysis is complete, perform an integrated supply/demand analysis for the PSD sector that accounts for overlaps and any potential double counting among PSD, RCI, TLU, and AFW policies. To account for the issue of credit associated with emission reductions, we propose to start with the Mitigation Case demand forecast, then develop a GHG Mitigation Case capacity expansion plan to meet that demand. This implies a RCI-PSD option analysis sequence and seems most consistent with the way expansion plans would be developed, given demand foresight.

PSD Baseline

An understanding of the Baseline capacity expansion plan, annual electricity generation and associated GHG emissions will be based on the New York State GHG Emissions Forecast developed by NYSERDA (2009). Electricity transmission and distribution losses are estimated at 9 percent on average, based on modeling work done by NYSERDA and the New York Independent System Operator²⁵, and are assumed to be constant across all regions. As the Baseline forecast is only available through 2018, a linear extrapolation will be made out to the end of the analysis period (i.e., 2030) consistent with an assumption that the system emissions intensity rate (i.e., tCO₂e/MWh) for the 2019-2030 period is the same as the 2018 level. Technical supporting documents for the Baseline forecast (i.e., technology performance assumptions, fuel prices, capacity additions, etc) have been provided by NYSERDA and will be used to better understand the Baseline modeling outputs.

PSD Mitigation

Electricity generation from GHG mitigation technologies are calculated at the technology level and aggregated up based on the policy design. For instance, the electricity produced by renewable sources in the Renewable Portfolio Standard are estimated based on the stipulated resource mix relative to the mix of fossil resources that would be displaced in the Baseline. An assessment of the mix of fossil resources displaced in the Baseline will be made on a policy-by-policy basis in consultation with NYSERDA and the Technical Work Group.

Cost Assumptions

The incremental costs to implement the PSD options are the difference between the levelized costs of GHG mitigation options and the levelized costs of the resources displaced in the Baseline. The assumptions associated with costs calculations are:

- Forecasted fossil fuel prices for the PSD sector and well as technology cost and performance assumptions will be consistent with those used to develop the Baseline power supply forecast.
- Forecasted technology cost and performance assumptions for GHG mitigation options will be consistent with those used to develop the NYSERDA Cost Curve study. These will be augmented/adjusted as needed in consultation with NYSERDA and the Technical Work Group.

²⁵ Personal communication with Ted Lawrence at NYSERDA on November, 12, 2008.

Electricity Imports

The GHG emissions associated with electricity imports assumes that the emissions intensity over the analysis period is a constant 0.36 metric tons CO₂/MWh on a consumption basis. This is based the State Energy Plan “starting point” generation, demand, and GHG forecasts. It is assumed that cost impacts associated with changes in electricity imports are based on the annual wholesale electricity prices.

Effects of Recent Actions

Relevant recent actions that are not included in the NYSERDA forecast will be accounted for to the extent possible. We assume that the effects of the Renewable Portfolio Standard are included in the NYSERDA electricity and fuel forecasts. It is important to note that the ‘Starting Point’ only includes the 25 percent RPS. The 45 by15 policy is a bit complicated in that the new 30% RPS is linked to a reduction in load leading to an output where new renewable generation is not much larger. The existing Integrated Planning Model (IPM) runs for the different cases will be reviewed to assess the prospects for a parameterized analysis (i.e., no new IPM runs). In any event, this issue will be further discussed with NYSERDA as the quantification gets underway.

Other Assumptions

The following assumptions are generic to all options:

- Real discount rate: costs and benefits from each option are discounted at a 5 percent real discount over the 2011-2030 period as specified by the Climate Action Plan Quantification Methods Memorandum.
- GHG emission factors: Fuel-based emissions factors are as specified by the Climate Action Plan Quantification Methods Memorandum.
- Technological Change: The impacts of technology learning on capital costs of PSD technologies will be folded into the levelized cost calculations consistent with assumptions developed in the NYSERDA Cost Curve study. The ongoing NYSERDA review of solar-PV price forecasts should be completed by the time the quantification gets underway. In addition, we will aim to incorporate any recommended assumptions from the EPRI review of the Cost Curve study.

Moreover, the quantification of each of the PSD policy options requires additional assumptions that are germane to each option. These are identified in the design for each option and will be incorporated into the analysis in consultation with NYSERDA and the Technical Work Group.

RCI Common Assumptions Memorandum - Draft

To: NYS Climate Action Plan Residential, Commercial/Institutional and Industrial Technical Workgroup

From: Hal Nelson and Steve Bower

CC: Tom Peterson, Jeff Wennberg, Randy Strait, Karen Villeneuve, Jodi Smits-Anderson

Subject: Assumptions used in the quantification of options for the RCI Technical Work Group

Date: July 26, 2010

This memo outlines proposed data sources used to quantify the greenhouse gas (GHG) impacts and costs for those RCI Technical Work Group policy options that are considered amenable to quantification. The memo will be reviewed in an upcoming Technical Work Group call so that comments on the assumptions may be made and alternative data sources recommended for Technical Work Group approval. Any changes to this memo will be incorporated and the revised memo will be used as documentation for the modeling results.

The scope of this memo only covers the major assumptions directly related to the quantification of the RCI policy options. Recall that the emissions reductions and costs in the quantification of the policy options occur against the backdrop of the inventory and forecast. The effects of the policy options are therefore incremental to the activity projected under the inventory and forecast. The assumptions embedded in the New York Inventory and Forecast were reviewed at during the February 5th, 2010 RCI Technical Work Group call.

Quantification Process

The analysis includes spreadsheet modeling techniques in which assumptions are transparent and readily accessible for review. The assumptions delineated in the following document are for the quantification of the policy options developed by the RCI Technical Work Group. This quantification of costs and CO₂ reductions entails the following steps:

- Develop stand-alone cost estimates for each quantifiable option
- Once completed, the stand alone options will be adjusted to reflect existing actions such as the NYS energy efficiency portfolio standard and the April, 2010 customer sited renewable portfolio standard. These are actions that are not in the reference case forecast, but are likely to occur. Adjusting for existing actions eliminates potential “double counting” of greenhouse gas reductions.

- To assess the RCI emission reductions without double-counting, it is necessary to consider overlaps and interactions within the RCI policies and measures as they affect similar types of energy use.
- Options will be also be modified to reflect overlaps between RCI options and other Technical Work Group options. Potential interactions occur between RCI policies and measures that deploy renewable energy with Power Supply and Delivery (PSD) and Agriculture, Forestry and Waste (AFW) mitigation measures. One interaction that could be modeled is the effect of New York’s renewable portfolio standard (RPS) and the Power Supply and Delivery policy options on the assumed carbon intensity of electricity delivered to the RCI sectors.

RCI Energy Reductions

Energy savings from efficient technologies and best practices are calculated at the technology level and aggregated up based on energy consumption at the relevant end use. For instance, the electricity savings from light emitting diode (LED) technologies are estimated based on the incremental energy efficiency of LED lighting over the assumed reference technology. These energy savings are then adjusted for lighting energy use as a percent of the RCI sectoral sales, less business as usual LED penetration. Electricity savings are also adjusted for transmission and distribution (T&D) losses according to the formula:

$$\text{Eq 1). Annual energy efficiency deployment: } [(technology \text{ or } practice \text{ electricity savings}) / (1 - T\&D \text{ losses})]$$

Annual baseline energy consumption and GHG emissions will be derived from the most recent NYSERDA NYS GHG Emissions Inventory.

- The baseline electricity demand comes from the “starting point” forecast for RCI sectors through 2030.
- The fuel consumption forecast comes from most recent NYSERDA forecast.

Electricity T&D losses are estimated at 9 percent based on modeling work done by NYSERDA and the NY Independent System Operator²⁶. Electricity T&D losses are assumed to be constant across all regions and load periods even though peak electricity T&D losses are higher than baseload T&D losses. Natural gas T&D losses are not initially accounted for as energy savings from avoided natural gas transmission and distribution usage are assumed to be modest. The GHG benefits from reduced gas demand will be discussed qualitatively, but if quantification of policies to conserve natural gas show significant reductions, then avoided fugitive methane emissions might be estimated.

Methodology for Avoided Carbon Dioxide (CO₂) Calculations

Energy reductions for fuel in physical units (Btu) will be converted into GHG emissions reductions according to their relevant emissions factors presented in the quantification methods memorandum. For electricity reductions, the GHG impacts for grid connected RCI policy options are quantified according to the following formula:

²⁶ Personal communication with Ted Lawrence at NYSERDA on November, 12, 2008.

*Eq 2). CO_2 Reductions in year_i: Electric efficiency deployment (GWh) in year_i * CO_2 intensity in tons per GWh in year_i*

To estimate emissions reductions from policy options that are expected to displace conventional grid-supplied electricity (i.e., energy efficiency) a straightforward approach is employed based on input from NYSERDA and other stakeholders. Consumption-based emission intensity has been developed that accounts for emissions from imported power, in-state generation as well as CO_2 emissions from transmission and distribution losses. A weighted average approach to in-state generation and imports was employed based on the State Energy Plan “starting point” generation, demand, and GHG forecasts. Imports over the period were credited at 0.36 metric tons CO_2 / MWh for all periods. The consumption based intensity divides CO_2 emissions from the power sector by electricity demand (instead of generation).²⁷ Due to reductions in forecasted T&D losses as well as increased penetration of renewables and other lower carbon fuels, the forecasted emissions intensity in metric tons CO_2 /MWh is forecasted to decline dramatically in NY in the near term. The following table shows the electricity emissions intensity assumptions employed:

Table E-6: Consumption-Based Electricity Emissions Intensity [2009 PLACEHOLDER]

Year	Tonnes CO_2 / MWh
2006	0.42
2007	0.38
2008	0.35
2009	0.33
2010	0.31
2011	0.31
2012	0.30
2013	0.30
2014	0.30
2015	0.29
2016	0.29
2017	0.29
2018	0.29
2019	0.29
2020	0.29
2021	0.29
2022	0.29
2023	0.29
2024	0.29
2025	0.29

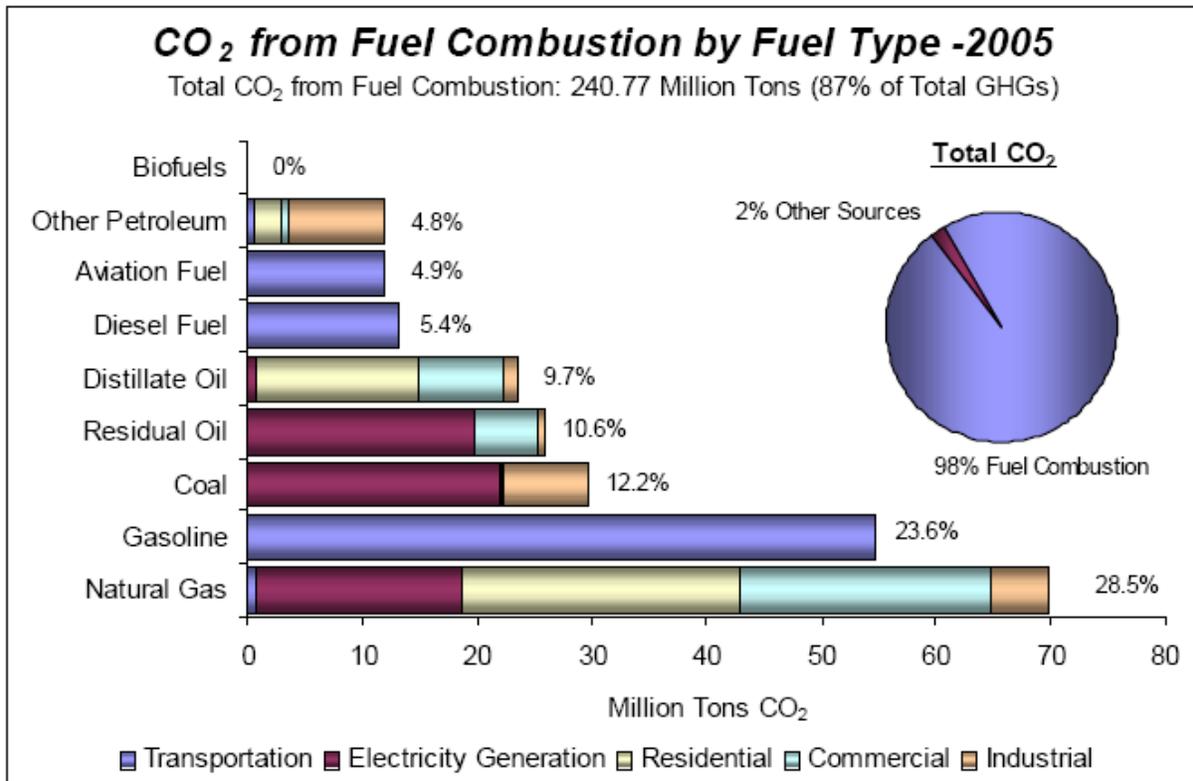
²⁷ The consumption based approach is slightly higher than the production based intensity. The consumption based approach makes more sense from a theoretical standpoint as emissions from T&D losses are mitigated from RCI end user activities.

Year	Tonnes CO ₂ / MWh
2026	0.29
2027	0.29
2028	0.29
2029	0.29
2030	0.29

Current electricity load forecasts are available through 2030.

This approach provides a transparent way to estimate emissions reductions and to avoid double counting (by ensuring that the same megawatt hours (MWh) from a fossil fuel source is not “avoided” more than once). It can be considered a “first-order” approach; it does not attempt to capture a number of factors such as the distinction between peak, intermediate, and baseload generation; issues in system dispatch and control; impacts of nondispatchable and intermittent sources such as wind and solar; or the dynamics of regional electricity markets. These relationships are complex and could mean that policy options affect generation and emissions (as well as costs) in a manner somewhat different than estimated here. Nonetheless, this approach provides reasonable first-order approximations of emissions impacts and offers the advantages of simplicity and transparency that are important for stakeholder processes.

Figure E-2. 2005 CO₂ Emissions in New York State



Cost Assumptions

The cost to implement the RCI options are the net difference between the avoided costs of energy and the cost of the energy efficiency measures where:

*Net costs (benefits): Energy efficiency deployment * (avoided cost of energy – levelized cost of measures including administrative costs)*

The assumptions associated with costs calculations are:

- Forecasted fuel prices for the RCI sectors come from the most recent NYSERDA price forecast.
- Avoided electricity prices from Optimal (2010) for the RCI sectors are used for avoided costs and are estimated in the following manner:
 - For each year following the end of the available forecast period, the prices are changed by the annual forecasted change in price of electricity from table 67 of the detailed outputs to the AEO 2010 for the NERC region.²⁸

Effects of Recent Actions

Relevant recent actions that are not included in the NYSERDA forecast will be accounted for to the extent possible. The federal Energy Independence and Security Act (EISA) of 2007 was signed into law in December 2007. This law contains several requirements that will reduce GHG emissions as they are implemented over the next few years. We assume that the effects of the EISA are included in the NYSERDA electricity and fuel forecasts.

Relevant updates to New York’s mandatory building energy codes are also identified in the analysis. NYS’ residential code is based on the 2004 International Code Council’s International Energy Conservation Code (IECC). For commercial buildings New York references the 2003 IECC code and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 standards.

Planned activities such as the NYS Energy Efficiency Portfolio Standard (EEPS) 15% efficiency target by 2015 (45 by 15), as part of the Governor’s proposal to have 45% of electricity come from renewables and energy efficiency, will be explicitly modeled as appropriate.²⁹ The April 2nd, 2010 RPS order will be included as a recent action “wedge” between what would have happened in the baseline through 2015 and the Climate Action Plan policies.

Evolving policies with market-driving effects such as the governor’s Executive Order 111 for state buildings, which ends in 2010, New York City legislation in response to the Mayor’s PlaNYC2030, and other currently planned energy efficiency interventions by NYSERDA, Long Island Power Authority (LIPA), and New York Power Authority (NYPA) will be analyzed, as

²⁸ <http://www.eia.doe.gov/oiaf/archive/aeo08/index.html>

²⁹ A scenario with the effects of the 15% energy efficiency savings by 2015 is estimated as the difference between the “starting point” load forecast and the 15x15 in the most recent forecast file.

budget and project time allow, to assess baseline penetration rates of selected efficiency measures.

Other Assumptions

The quantification of each of the policy options requires additional assumptions that are germane to each option and are described in detail in the policy option document. For instance, there are many building code assumptions in that policy option. However, the following assumptions are generic to nearly all options:

- Real discount rate: costs and benefits from each option is discounted at a 5 percent real discount over the 2010-2030 period as specified by the NY Climate Action Plan Quantification Methods Memorandum.
- Technological Change
 - An examination of historical energy efficiency equipment, including compact florescent lights, solar PV, heat pump water heaters, and other measures shows learning curves that result in capital cost reductions over time. The installed costs and value of energy savings are sensitive to future conditions. Learning curves will be used for selected measures to account for economies of scale in production which result in cost reductions over time. Learning curves will come from the most recent, reliable data sources.

TLU Common Assumptions Memorandum - Draft

To: New York Climate Action Council
From: Hillel Hammer
cc: Tom Peterson, Jeff Wennberg, Randy Strait, Sandi Meier, Ernest Tollerson and Paul Beyer
Subject: Analysis and Assumptions for Transportation and Land Use Policy Options
Date: July 12, 2010

This memo summarizes key elements of methods of analysis aimed at estimating potential greenhouse gas (GHG) emission reductions and cost effectiveness of Transportation and Land Use (TLU) policy options in the New York State Climate Action Plan process. The process of policy analysis is intended to support state-specific design and analysis of draft policy options, while providing for both consistency and flexibility.

Key general guidelines for policy analysis as conducted by Center for Climate Strategies' consultants are presented first, followed by specific elements of policy analysis methods and assumptions for Transportation and Land Use issues.

1. GENERAL GUIDELINES FOR POLICY ANALYSES

The following outlines the central guidelines for policy analysis. For a complete description of all general guidelines for policy analysis, see *Draft Quantification Methods Memorandum—New York State Climate Action Plan*, July 2010 ('Quantification Memo').

Fuel Cycle Coverage

GHG reductions for each mitigation option in TLU will be based upon the full fuel cycle because information is available to support this type of analysis for this sector (see more in Section 2 below).

Life Cycle Coverage

As mentioned above, there are other mitigation policy options that will also have important life cycle impacts. These include those associated with reducing non-fuel consumables, such as concrete and steel. Life cycle impacts will be reported for each source for which information is available to support a life cycle analysis. For TLU, this will focus mostly on construction materials, where possible. It will not be possible to identify in-State versus out-of-state sources for these construction materials.

Pollutant Coverage and Global Warming Potentials

The analysis will cover the six Kyoto GHGs, presented as carbon dioxide equivalent (CO₂e), which indicates the relative contribution of each gas to global average radiative forcing. This will be based on the approach outlined by the Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report, consistent with the draft GHG emissions inventory and forecast

for the state of New York and with the U.S. Environmental Protection Agency (EPA) and IPCC guidance.

Time Period of Analysis

For each sector, life cycle emission reductions and incremental life cycle costs will be calculated relative to the characteristics of the Baseline that would otherwise prevail in New York up through the end of the planning period, 2030.

The analysis will report annual emission reductions for 2020 and 2030. The net present value of the cumulative costs, and cumulative emission reductions, will be reported for the period starting with the initial year of the phase-in of the policy, up through 2030. For long-term capital investments, the investment will be annualized over the lifetime of the project operation, and the portion included in the analysis period will be included.

Transparency

Analyses will be performed in spreadsheet format to the extent practicable, to enable maximum transparency and facilitate review. Exceptions to this will be only in cases where external models such as GREET are required (see details on the model in Section 2).

Data sources, methods, implementation mechanisms, key assumptions, and key uncertainties will be documented and supported by references to provide transparency on how the key analytical outputs for each policy option were developed and applied. Information provided by the state agencies and project participants will be used to ensure best available data sources, methods, and key assumptions using their expertise and knowledge to address specific issues in New York State. Modifications will be made through facilitated discussions.

Key Analytical Outputs and Metrics

GHG Emission Reductions

Net GHG reduction potential in physical units of million metric tons (million metric tons or MMT) of carbon dioxide equivalent (CO₂e) will be estimated for each quantifiable policy for target years 2020 and 2030, as well as the total for the entire analysis period.

Costs

Net capital, operating and maintenance (O&M), and fuel costs will be estimated for each of the policies that are determined quantifiable. Costs will be discounted as a multi-year stream of net costs to arrive at the “net present value cost” associated with implementing new technologies and best practices. It is proposed that costs be discounted in constant 2005 dollars using a 5 percent annual real discount rate. The nominal discount rate will be calculated by adding the projected inflation rate over the analysis period. Capital investments will be represented in terms of annualized or amortized costs over the project period. (See the section on “Cost Analysis Methods” for additional details.)

Cost savings (e.g., fuel savings) will be included, represented as a negative cost. If significant financing costs or split incentives (cases where the benefits are not reaped by the investor) are expected, these will be identified.

Cost-effectiveness

The cost effectiveness—cost or savings per tone—for each quantified policy, represented as dollars per MMt CO₂e (\$/MMtCO₂e), will be calculated by dividing the present value cost by the cumulative (undiscounted) reduction in GHG emissions. When combined with GHG impact assessments, the results of these cost estimates will be aggregated into a sectoral summary table and sector and economy-wide stepwise marginal cost curves.

Direct vs. Indirect Effects

“Direct effects” are those borne by the entities subject to or directly affected by the policy or entities implementing the new policies. For example, direct costs are net of any financial benefits or savings to the entity. Direct effects will be quantified.

“Indirect effects” are those borne by entities other than those defined for “direct effects”. Indirect effects will not be quantified.

Non-GHG (External) Impacts and Costs

Environmental co-benefits such as reductions in criteria air pollutants, which in turn would lead to reduced public health impacts from productive activities in New York, will not be quantified. Qualitatively, CCS will document measures that are expected to have other non-GHG impacts, including, but the physical and monetary costs or savings associated with these external impacts will not be included explicitly in this analysis.

Uncertainty / Sensitivity Analysis

Key uncertainties and feasibility issues will be identified and discussed qualitatively.

Calculation of Emissions

Emission reductions will be estimated incremental to baseline emissions based on the change (reduction) in emissions activity (e.g., reduced vehicle miles traveled—VMT), calculated either directly, by using the same factors applied in the baseline inventory (e.g., reduction in fuel consumed and fuel-based emission factors), or as a fraction of the baseline inventory (e.g., fraction of baseline VMT and associated emissions reduced).

Emissions associated with electricity consumption will be calculated based on the procedures outlined for the PSD sector. Electric demand by vehicles may be calculated using the NY-GREET model (see Section 2 below).

Calculation of Costs

Net capital, operating and maintenance (O&M), and fuel costs will be estimated for each of the policies that are determined quantifiable. Costs will be discounted as a multi-year stream of net costs to arrive at the “net present value cost” associated with implementing new technologies and best practices. It is proposed that costs be discounted for all options in constant 2005 dollars using a 5 percent annual real discount rate. The nominal discount rate will be calculated by

adding the projected inflation rate over the analysis period.³⁰ For full details on cost calculation, see the Quantification Memo.

Documentation

Documentation of the work will be completed in a template format that addresses the following items (among others):

Work Group Sector

Name of policy option

Policy Description

Policy Design (Goals and Timing for implementation and parties involved or affected by implementation of the policy.)

Implementation Mechanisms

Quantification: Estimated GHG Savings and Costs per MtCO₂e (GHG reduction potential in 2020 and 2030, Cumulative GHG reduction potential, net cost, data sources, and quantification methods)

Key Assumptions and Uncertainties

Co-Benefits and External Costs (qualitative discussion)

POLICY ANALYSIS METHODS AND ASSUMPTIONS SPECIFIC TO TRANSPORTATION AND LAND USE ISSUES

Policy analysis of transportation and land use issues is inherently complex, given the inter-relationships between transportation systems, land use, and other important aspects of societal well-being. Policy analysis methods for transportation and land use as conducted by consultants for CCS is based upon many years of well-established professional practice and methods that are widely accepted in the fields of public policy analysis, urban and transportation planning, transportation engineering, and environmental sciences. The information provided here provides information about analyses relating to the potential changes in GHG emissions in the transportation sector resulting from the combustion of transportation fuels and use of electric power. In addition, GHG emissions associated with the production and transport of standard and alternative fuels ('fuel-cycle emissions') and with construction activity and materials are included where information and methods are readily available.

There are four general categories of factors that impact upon the emission from the transportation sector: vehicles, fuels, systems, and travel activity. These four factors interact in a complex

³⁰ The inflation rate for the analysis period is assumed to be 2.2%, subject to approval by the Integration Advisory Panel and Climate Action Council. Capital and other costs reported in nominal dollars will be converted to 2005\$ using the inflation rate for the NY state region as reported by the Bureau of Labor Statistics (<http://www.bls.gov/ro2/news.htm>)

fashion to affect GHG emission. In addition, direct and indirect emissions may be associated with construction and infrastructure.

Underlying Premises and Methodology

Simple spreadsheet modeling techniques in which assumptions are transparent will be used for the analyses as much as possible. To ensure consistent results across options, common factors and assumptions will be used for the following items:

Independent and integrated analyses: Each option will first be analyzed individually and then addressed as part of an overall integrated analysis.

Fuel Costs and Projected Escalation: Fuel cost estimates will be based on common sources wherever possible. For example, fossil fuel price escalation will be indexed to the U.S. Department of Energy (DOE) projections as indicated in their most recent Annual Energy Outlook (AEO).

Consumption-Based Approach: The analysis uses a consumption-based approach where emissions are calculated on the basis of the consumption of transportation fuels (represented as direct fuel consumption or as vehicle miles traveled) to provide energy to New York consumers, as opposed to a production-based approach, which considers the emissions from in-state production of transportation fuels.

Life cycle Emissions: Life cycle greenhouse gas emissions are considered on a case-by-case basis. The primary focus of the analysis of Transportation and Land Use issues is upon the direct combustion of transportation fuels to provide energy. Energy cycle of fuels will be included, and construction impacts will be included where practicable.

Overlap with Other Sectors: Where TLU options overlap with options being considered in other Technical Work Groups, the analysis for these options will be conducted in close coordination with the assumptions and other inputs used in other CCS analyses.

Data Sources

TWG members are often in a good position to obtain and provide data sources that are specific to New York, and these will be used as much as possible, including data already provided by NYSDOT, MTA, and others. Where New York-specific information cannot be readily obtained from the Technical Work Group, the analysis relies on other local data available to the consultants, and on published data from the DOE, EPA, national laboratories, other federal agencies, and other state climate change processes.

The analysis of renewable fuels and the use of electricity for vehicles will be based on output from the New York-specific application of the Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model (NYGREET), prepared for this effort (also used in the baseline inventory).

General data sources will include:

Baseline Historical Energy Consumption by Sector

Historical energy consumption in the state, by sector, is from the DOE Energy Information Administration (EIA) State Energy Data available at <http://www.eia.doe.gov/emeu/states/seds.html>.

Baseline Historical Vehicle Fleet, Fuel Use, and Travel Activity Data

Baseline data on the state vehicle fleet, fuel use, and travel activity data is obtained from the latest inventory and forecast provided by NYSERDA. (Data sources, and methods of analyses for the baseline and forecast are described in the inventory and forecast.)

Baseline Forecast GHG Emissions

Baseline forecasts of future GHG emissions for the transportation and land use sector is obtained from the inventory and forecast report.

Energy Price Projections through 2030

Energy prices by region are from the EIA Supplemental Tables to the AEO 2010, with projections through 2030. Adjustments to the EIA projections are made on a case-by-case basis.

Cost Inclusion

The analytical methods being used can incorporate a wide variety of costs, depending on the availability of cost data. Fuel costs are incorporated into all analyses where relevant. Other types of costs will be explicitly considered in the analysis if they can be readily estimated. Types of costs that may be incorporated include:

- Annualized Capital costs levelized (amortized);
- Operations and maintenance cost; and
- Administrative costs.

Types of costs that will not be incorporated include

External costs, such as the monetized environmental or social benefits and impacts (e.g., the cost of damage by air pollutants on structures and crops), quality-of-life improvements, and health impacts and benefits (e.g., improved road safety);

Energy security benefits; and

Macroeconomic impacts related to reduced or increased consumer spending, and shifting of cost and benefits among different sectors of the economy.

Appendix F

2050 Visioning:

Brookhaven National Laboratory Report

As part of its climate action planning, the state of New York is unique in undertaking a visioning process to assist the long-range goal of reducing greenhouse gas emission 80 percent below the levels emitted in 1990 by the year 2050. To develop a plan capable of setting in motion the radical, long-term changes required to achieve the 80 by 50 goal, the Council and its technical work groups and panel — indeed, decision makers at many levels — must be able to imagine the kind of low-carbon clean energy future toward which they are working.

An initial step in that visioning process was a conference held January 5, 2009, *Envisioning a Low-Carbon Clean Energy Economy in New York*. The conference, organized by the New York Academy of Sciences, Brookhaven National Laboratory, the New York State Energy Research and Development Authority, and the New York State Department of Environmental Conservation, involved members of the Climate Action Council, the Integration Advisory Panel, and the Technical Work Groups.

Led by subject matter experts, the participants in the workshop explored innovative strategies for meeting the State’s energy needs, reducing energy demand, managing greenhouse gas (GHG) emissions, driving technological change, and creating economic opportunities for “green-tech” in New York. The workshop considered specific scenarios that outlined possible pathways to reducing GHG emissions. The purpose was not to validate a particular pathway, but rather to explore possibilities and their implications, as well as to identify obstacles to achieving the goal.

The January conference led to the creation of the report, *Envisioning a Low-Carbon Clean Energy Economy in New York*, produced by Brookhaven National Laboratory and appended here in its entirety and keeping its original pagination.

Envisioning a Low-Carbon 2050 for New York State

**A white paper submitted to the
New York State Climate Action Council**

**by Gerry Stokes and Patrick Looney
Brookhaven National Laboratory
Upton, NY 11973**

October 1, 2010

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Important note to readers:

This is the first complete draft of a paper designed to inform the NYS Climate Action Council's work to develop a State Climate Action Plan.

The Council's mandate is uncommonly broad in scope. It has a planning horizon far longer than what most planners address. It entails large uncertainties. No clear precedent for an enterprise of this scope exists.

Consequently, this draft paper is necessarily provisional. As the planning process proceeds, the paper will be revised, and it will steadily gain in value as fresh insights are acquired and the knowledge base it draws from expands.

One feature of this paper is a description of three scenarios that illustrate different versions of a low-carbon 2050 future for the state. It's important that readers understand that these scenarios are offered for illustrative purposes only. In no sense do they constitute the elements of a plan, and indeed even a casual review of them reveals that there is no way in which they could be fashioned into a plan. Rather, they're intended to facilitate and provoke thinking about the future.

We hope other parties will generate their own 80x50 scenarios and share them. The ability to *imagine* a sustainable future, model it rigorously, and explore it is as vital to achieving that future as the clean-energy technologies, best management practices, and behavioral changes that must be developed, advanced, and adopted.

SUMMARY

The State of New York aims to reduce state greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050. The fact that the state is already more energy efficient than most other states makes this goal particularly ambitious. A State Climate Action Council is charged with developing a draft Climate Action Plan by November, 2010. Toward this end, it has organized technical work groups and an integration advisory panel of stakeholders and experts.

To develop a plan capable of setting in motion the radical, long-term changes required to achieve the 80x50 goal, the Council and its team must be able to imagine the kind of low-carbon future toward which they are working. To facilitate this, the Council also formed a [2050 Visioning Advisory Panel](#). Comprising experts from many fields, that panel was convened at a workshop held on January 5, 2010.

This draft visioning paper draws from insights and knowledge shared at that workshop, and from other expert sources. It also draws from three GHG mitigation scenarios for 2050 that we developed for the workshop to illuminate how a low-carbon future might be achieved, and what it would mean. Making assumptions about future energy demand, patterns of energy use, the technologies that might be available to supply needed energy with reduced emissions, and what their levels of performance might be, we estimated emissions for each major sector of the state's economy. We found that reaching the 80x50 goal is challenging and that modeling required aggressive assumptions.

Together, the workshop, scenario development, and the crafting of this visioning paper constitute a "visioning process." Its focus has been manifold: an examination of technologies that might prove scalable and those that might be dead ends, of technical issues that require assessment, of policies that favor or constrain GHG reductions, and of management and societal changes needed to reduce emissions.

While the state's energy future cannot be predicted, some points are already clear, among them, these:

- Reducing emissions is imperative because atmospheric levels of GHGs are already perilously high, and emissions are cumulative – and there are real costs associated with inaction.
- The 80x50 goal is ambitious, and achieving it will require investments in new energy systems and infrastructure that have very low or no net carbon emissions. Patterns of energy use will also need to change.
- Energy efficiency is an essential, but not sufficient, strategy that can be aggressively pursued today.

- A broad shift from reliance on burning fossil fuels to electricity generated from low- or no-carbon sources, or widespread use of carbon capture and sequestration, will be needed.
- Transportation and buildings (residential and commercial) will have to move away from reliance on combustion of fossil fuels to alternate sources with significantly lower carbon or no carbon emissions.
- Development and redevelopment based on smart growth principles, as well as the building design practices, building technologies, and construction methods can significantly reduce the energy demand for buildings, as well as transportation.
- Incremental, short-term planning cannot achieve the goal. Near-term decisions – both those taken and not taken – can preclude longer-term options, such as infrastructure projects requiring long lead times. Key climate strategies *must* reflect this inexorable reality.
- The goal must be pursued in part through extensive, long-term partnering among all levels of government and across the region, and between the public and private sectors. It will take sustained effort on the part of all.

THE BROAD CONTEXT FOR THIS PAPER

In the face of climate change, the stakes are so high, the challenge so immense, and the opportunities so richly promising that business as usual and conventional wisdom are themselves risky. Innovation is imperative — not only in technology but in ways of thinking, working, and living.

In fact, what's demanded transcends "innovation": transforming an entire economy from largely carbon-based energy sources to largely carbon-neutral sources in a scant 40 years will be a true revolution, a radical shift that can renew New York's economy, enhance its natural environment, and improve its citizens' quality of life for generations to come.

For this revolution to succeed, institutions must be mobilized, businesses must adapt or fail, and individuals, families, and communities must make better-informed energy choices. And all of this change must be scaled up massively and rapidly.

The 80x50 challenge

Recognizing the benefits of action and the risks of inaction, in August 2009 the Governor signed [Executive Order 24](#), which tasks the State to reduce GHG emissions from all sources within the state to a level 80% below the 1990 level by 2050. It establishes a Climate Action Council that is to develop a Climate Action Plan to achieve that goal, taking into account economic and other considerations. The plan is to be drafted by November, 2010. The Council will hold public comment hearings on the draft and after reviewing comments prepare a final plan.

That plan will be reviewed annually and revised as appropriate. The Executive Order says it "is not intended to be static, but rather a dynamic and continually evolving strategy to assess and achieve the goal of sustained reductions of greenhouse gas emissions."

To advance and inform its work, the Council has convened stakeholders from New York, as well as experts from New York and beyond, and organized them into technical work groups and an integration advisory panel. Working in support of the Council and these groups is the [Center for Climate Strategies](#). The Council's comprehensive [web site](#) offers detailed information about its work, and it links to the *New York Greenhouse Gas Emissions Inventory and Forecast*. Readers unfamiliar with the Council are urged to consult the site for essential information that complements this paper.

How visioning contributes to the Council's work

To develop a plan capable of setting in motion the radical, long-term changes required to achieve the 80x50 goal, the Council and its technical work groups and panel must be able to imagine the kind of low-carbon clean energy future toward which they are working. To

facilitate this, a [2050 Visioning Advisory Panel](#) comprising experts drawn from many fields was convened at a January 5, 2010, workshop held at the New York Academy of Sciences. At the workshop, the experts made presentations and responded to concerns and questions from the floor. (The link above leads to a link to a webinar of the workshop, the slides speakers showed, and the agenda.)

This draft paper draws from insights and information shared at the January workshop. It also draws from many other expert sources, such as reports from the National Academies of Science. And it draws from three GHG mitigation scenarios for 2050 that we developed for the workshop, described below. Together, the workshop, the development of scenarios, and the crafting of this visioning paper constitute what may be termed a “visioning process.”

The focus of the process has been manifold: an examination of technologies that might prove scalable and of those that might be dead ends, of technical issues that must be addressed, of policies that favor or constrain GHG reductions, and of management and societal changes needed to reduce emissions. Of course, policies that favor GHG reductions must be implementable. But for a time horizon so far distant, at this early stage, technical feasibility and cost considerations can be considered only in broad-brush terms. This paper treats them accordingly.

Our scenarios suggest that, in concept, the 80x50 goal is technically possible. The overall visioning process makes clear that incremental, short-term planning alone cannot meet the goal and that even a sophisticated long-term approach must surmount serious challenges. This in turn underscores how important it is that climate change vulnerability analyses and adaptation planning proceed on equal footing with mitigation efforts.

But the scenarios reveal a world of opportunities, too, that hold tremendous potential for the state’s economy and its citizens’ well being.

THE APPROACH TO ENVISIONING A LOW-CARBON 2050

The technical work groups that are contributing to development of the State's Climate Action Plan process are responsible for recommending specific strategies, policies, and actions for the Council's consideration. The visioning process, defined above, was designed to complement their work. Scenarios are a uniquely valuable tool for this purpose. Scenarios have been widely and routinely used, for many years, in many fields, as a tool for exploring options and contingencies. The three scenarios we developed for the State's January visioning workshop investigated the technical feasibility of the 80x50 goal and identified some technology options and best practices that could achieve the goal. The scenarios also helped us identify some significant technical barriers and policy issues that might facilitate or constrain those options.

To model and gain insight into possible futures, we "worked backward" from an imagined mid-century New York that has far lower GHG emissions. Making assumptions about future energy demand, patterns of energy use, what technologies might be available to supply energy and reduce emissions and what their levels of performance might be, we estimated emissions for each major sector of the economy, considering many interchangeable elements that might be dictated by policy implementation, technology breakthroughs, or market developments in the US and abroad.

The value of the scenarios is in providing a framework for thinking concretely about how energy efficiency, new energy technologies, fuel switching, best practices, and other matters might shape the path to a low-carbon future. Scenario modeling can also provide insight into performance levels for new energy technologies such as plug-in hybrid electric vehicles (PHEVs), or emission-reduction technologies such as carbon capture and storage (CCS).

All three of the 80x50 scenarios share important characteristics:

- An end state is postulated for each major energy-consuming sector of the economy: Transportation, Electricity Production and Distribution, Residential Buildings, Commercial Buildings, and Industrial. These end states are largely characterized by their technological characteristics, such as low carbon-emitting central generation of electricity, electric vehicles, and net-zero carbon emission buildings.
- Next, the ramifications of these technology options are examined. For example, if the state were to depend on hydrogen as a transportation fuel, how would the hydrogen be produced? Similarly, if the goal is low-carbon electricity central generation, what are the technology options for generating that power?
- Finally, the resulting scenario is referenced to a projection of what the energy use may be in absence of carbon abatement policies; that is, in the "business as usual case" (BAU). This comparison illuminates, for example, the magnitude of energy-efficiency gains that might be required, or the extent to which projected

transportation needs that light duty vehicles would otherwise meet could be met by expanded mass transit instead.

THREE SCENARIOS FOR 2050

Models, assumptions, and limitations

The three scenarios were designed to answer these basic questions:

- What are possible, illustrative scenarios in which NYS GHG emissions would be ~80% lower than the 1990 level of ~251.4 million metric tons (MMt) of CO₂ equivalent (CO₂e)? (a goal of about 51 MMt)
- What are the implications of such scenarios?

To support the modeling exercise, a macro model of statewide GHG emissions was developed. Data are presented in Table 1, below. Emissions data for 2007 are the most recent available and are considered “current” for the purpose of this paper. NYSERDA projects that 2025 annual GHG emissions will be 266 MMT CO₂e, a relatively small increase from current levels. The relative contributions of the various sectors remain unchanged, except that the “Other Source” category (non-fuel combustion) is projected to surpass residential emissions by 2025. (“BAU” is the “business as usual projection.”)

Table 1. Sector GHG Emissions for Select Years (in Million Metric Tons CO₂e)

	1990	2007	2025	2050
	(actual)	(actual)	(forecast)	(BAU Projection)
Transportation	72.9	88.4	93.4	114.3
Electric	64.5	49.2	42.9	75.5
Electric Imports	1.7	7.4	7.6	-
Residential	34.1	37.6	34.7	40.8
Commercial	26.8	27.3	30.1	35.4
Industrial	25.0	19.2	18.7	21.9
Other	26.5	28.7	38.5	39.0
TOTAL	251.4	257.7	266.0	326.6

Scenario modeling was a rigorous process that began by estimating the total energy demand that might have to be met in 2050 in each sector. This was done by extrapolating current forecasts and assuming modest growth in state GDP and hence energy demand.

These assumptions create the future “business as usual” (BAU) emissions scenario – the case that perpetuates the path we are on. BAU energy demand projection estimates the energy supply needed to support the state’s economy in 2050 given our current patterns of transportation, energy use and efficiency.

The foundation of our scenario development is a state-level, coupled-sector macro model of energy supply flows and corresponding (calculated) emissions for each sector of the economy. In addition, possible reductions in non-energy related emissions (the “Other”, non-energy related category) were estimated.

Table 2. Estimated Energy Demand by Sector

	2007 (actual)	2025 (forecast)	2050 (BAU Projection)
Transportation			
LDV/HDV VMT	136B Miles	170B Miles	224B Miles
Aviation	210 Mbtu	222 Mbtu	240 Mbtu
Electric	165,000 GWh	187,000 GWh	270,000 GWh
Residential	591Tbtu	629Tbtu	721Tbtu
Commercial	533Tbtu	557Tbtu	587Tbtu
Industrial	191 Tbtu	180 Tbtu	180Tbtu

In the table above “LDV” means “light duty vehicle; “HDV” means “heavy duty vehicle; “VMT” means “vehicle miles traveled.”

We then took the energy demand forecast for each sector, presented in Table 2, above, and traced energy flows through each sector as primary energy (e.g., coal, biomass) and energy carriers (e.g., gasoline, #2 and #6 oil, coal, etc.) would be used for such purposes as creating electricity, heating homes, providing power for businesses and manufacturing sectors, and fueling light duty and heavy duty vehicles. For each of those uses, we calculated corresponding emissions. Fuel energy content and emissions factors for combustion come from [US EPA data tables](#).

Significantly, unlike conventional “wedge” models, which treat sectors as freestanding, the coupled-sector model we employed reflects the fact that switching technologies in one sector may raise or lower demand in another. For example, two scenarios (the “Yellow” and “Ultraviolet”) depend on widespread use of PHEVs in the transportation sector, resulting in a

decrease in gasoline demand and an increase electricity demand; thus, primary energy demand switches to the electricity sector.

A note of caution: The scenario modeling provides insights into how technologies and patterns of energy use may have to change to meet emissions targets. But there are limitations to using the scenarios. This sort of modeling is not a practical planning tool, as it does not account for the crucial factor of scalability, or for economic, regulatory, and other barriers to the implementation of any given technology, including the availability of the raw material required. Nor does it take into account lifecycle analyses of nuclear power and renewable energy technologies. The models also do not consider the future interaction between a changing climate and energy use and impacts on the performance of different technologies.

The models do include estimates of the performance of new and emerging energy technologies for which the predicted development time scales are commensurate with the State's 40-year planning timeframe. Assumptions about the performance of new, emerging energy technologies are based on credible estimates from available literature, though there can be no guarantee that as-built systems will meet the estimated levels of performance, be economically viable, or penetrate the market at rates needed to meet assumed levels.

A note on methodology and references: For more information on methodology and data sources used in our modeling, please see Appendix A. For more detail on the scenarios, see Appendix B.

Basic strategies for reducing emissions

Developing scenarios that illustrate potential approaches to meeting the 80x50 emissions target of ~50 MMT CO₂e requires recognition of the fact that those emissions result from activities that power our society and our economy, providing food, shelter, heating and cooling, communications, transportation, and innumerable other things essential to well-being. Cutting GHG emissions could have real-world consequences if low-carbon or no-carbon energy sources don't adequately replace fossil sources.

The scenarios rely on four key strategies to reduce GHG emissions:

- The simplest and the most cost-effective is energy conservation through energy efficiency.
- Reducing combustion from fossil fuels is another obvious strategy, as that combustion accounts for about 87% of all GHG emissions in New York State, with the largest fraction coming from the transportation sector (38%), followed by on-site combustion in the residential, commercial, and industrial sectors (37%), and then from electricity generation (22%). All scenarios assume that combustion of fossil fuels should only be used when and where necessary, or where controls such as CCS

effectively limit emissions. Minimizing point sources of combustion such as vehicles and use of oil and natural gas for heating, and switching to electricity, coupled with simultaneously reducing the GHG footprint of the electricity supply, thus constitutes the second strategy.

- The third strategy is to drive fuel switching where combustion must still be used, as in aviation and cement production, to minimize the GHG footprint.
- Using local, point-of-use renewable energy technologies such as solar to reduce the reliance of homes and businesses on centrally generated electricity is the fourth strategy.

By varying these strategies and devising portfolios of energy technologies and practices that could implement them, we created three scenarios that we named “Yellow,” “Deep Blue,” and “Ultraviolet.” The Yellow scenario falls far short of the 80x50 goal; the other two scenarios meet it, in different ways.

The Yellow scenario

The Yellow scenario does not meet the ~50 MMT CO₂e GHG emissions challenge. It is intended to be a “first cut” at reducing GHG emissions through increased efficiency: the adoption of more efficient energy technologies that are largely available today, or will be soon. This scenario assumes a significantly different mix of light-duty vehicles (LDV) in use in 2050, with 30% being conventional internal combustion engines with an average of 37 mpg, 30% being hybrid electric vehicles (HEV) with an average of 50 mpg, and 40% being plug-in hybrid electric vehicles (PHEV) with 95% all-electric miles. This produces a modest increase in demand in the electricity sector of about 20,000 GWh. The use of intermodal freight shipping is assumed to reduce vehicle miles traveled (VMT) for HDV by about 30%.

In the electricity sector, it’s assumed that New York State wind and hydro-electric generation will be built out to meet the maximum forecasts developed by NYSERDA, and that there will be a very significant increase (up to 100,000 GWh) of utility-scale solar electric generation or other renewable source such as off-shore wind. Where combustion is used for electricity, a switch to higher-efficiency natural gas combustion turbine (NGCT) and integrated gasification combined cycle (IGCC) power plants with CCS at 90% is assumed. It’s also assumed that present levels of nuclear power generation can be maintained. Transmission and distribution losses are reduced by 50% to an average of 4% for the entire system. Residential, commercial, and industrial sectors reduce electricity demand via Energy Star+ efficiency gains.

This scenario includes elimination of 75% of all fossil fuel combustion in the residential and commercial sector, with natural gas and liquid fuels replaced by electricity, some generated on-site via solar (about 10% of the energy demand), and the balance generated at utility

plants. Industrial emissions are reduced by curtailing fossil fuel combustion overall by 75% and using only natural gas and #2 oil; coal is eliminated in favor of natural gas.

Reductions in non-energy emissions (the “Other” category) assume elimination of sulfur hexafluoride (SF₆) dielectric from the transmission and distribution grid. Per molecule, SF₆ has the highest GHG warming potential, about 23,900 times that of CO₂. Reducing natural gas line leaks (by 50%), implementing a broad and aggressive *reduce, reuse, and recycle* policy, and eliminating leaks of alternative refrigerants (hydrofluorocarbons [HFCs]) would reduce emissions from these sources significantly.

The Yellow scenario results in about 114 MMT CO₂e emissions, a reduction of 55 percent below the 1990 level. It thus falls far short of the 80x50 goal – a sobering fact, given how much it differs from today’s energy patterns.

The Deep Blue scenario

The Deep Blue scenario meets the ~50 MMT CO₂e GHG emissions challenge. It begins with the efficiency savings outlined in the Yellow Scenario and then explores alternatives if fossil fuel combustion in the residential and commercial sectors were to be eliminated, thereby driving an increase in electricity demand. Some of the increased electricity demand is assumed to be met with a larger fraction of point-of-use solar.

The Deep Blue scenario explores the impact of widespread adoption of hydrogen-powered light-duty vehicles for 100% of the LDV VMT with an equivalent of 65 mpg. The scenario assumes that hydrogen is produced through high-temperature steam electrolysis using gas-cooled high-temperature nuclear reactors. Because this approach employs a carbon-free electricity source, emissions are minimized. The calculations suggest the need for ~5 to 7 GW of nuclear capability for electrolysis. Gas-cooled reactors are well known conceptually, but significant technological and regulatory developments are needed. An alternative source of electricity could involve the use of IGCC or natural gas combined cycle (NGCC) with CCS. High-temperature steam electrolysis is an unproven technology at this time. The scenario does not address infrastructure issues associated with the transformation to a hydrogen-based transportation system.

The scenario assumes that 100% of all fossil fuel combustion in the residential and commercial sectors is eliminated and that the use of natural gas and liquid fuels is replaced by electricity, some generated onsite via solar (about 40% of the energy demand), the balance generated at utility plants. Industrial emissions are reduced by curtailing fossil fuel combustion overall by 75% and using only natural gas and #2 oil; coal is eliminated in favor of natural gas. Importantly, 8.4 MMT of the 13 MMT in emissions in the industrial sector are residual emissions from asphalt, petrochemical production, etc. It will be important to devise methods for curbing emissions from asphalt production to make further reductions.

Electricity demand is met from carbon-free sources, including 30% from nuclear (including 2 new plants that would increase nuclear power generation by 25,000 GWh, not counting the additional reactors required for hydrogen generation), 30% from renewables (maximum hydro, wind, and 100,000 GWh of solar), and 40% from NGCC plants with 90% CCS. It is important to note that the emission levels from NGCC limit generation from this source unless CCS is achievable at levels higher than 90%. This would make the future use of natural gas or coal for the electricity sector dependent upon the viability of CCS for locations and geologies within the state, and upon the amount of CO₂ that can ultimately be stored.

In addition, the Deep Blue scenario assumes that emissions in aviation and the residential, commercial, and industrial sectors could be significantly reduced through the use of in-state, bio-derived oils for transportation (diesel), aviation (jet fuel), and heating. Given the potential for reduced emissions in the aviation, residential, and commercial sectors – as well as for HDV transportation – these replacement fuels warrant serious consideration, as do studies of the feasibility of supplying bio-derived oils for fuel from within the state. At present, net carbon emissions from these sources are assumed to be zero or close to zero, as carbon emitted by combustion of the biofuel is offset by carbon sequestered by plants grown to supply fuel. (See EPA's [2009 U.S. Greenhouse Gas Emissions Inventory Report](#).) Further study regarding the total carbon cycle associated with the use of these fuels is warranted to validate the emissions assumptions.

The Deep Blue scenario estimates emissions at 53 MMT. It thus achieves a 79 percent reduction in GHG emissions below the 1990 level.

The Ultraviolet scenario

Another possible future was devised that would also meet an 80 percent reduction by 2050. Like Deep Blue, the Ultraviolet scenario is much more aggressive than the Yellow scenario. It too begins with the efficiency savings outlined in the Yellow scenario and explores alternatives if fossil fuel combustion in the residential and commercial sectors were eliminated, thereby driving an increase in electricity demand. A part of this electricity demand is met through local, point-of-use solar.

The Ultraviolet scenario explores the impact of shifting to widespread use of PHEVs where 95% of VMT are all-electric miles, with 5% of VMT coming from bio-ethanol at 50 mpg. This is an aggressive goal, well beyond current predictions for most studies of PHEV market penetration and performance improvements through 2030. Significant increases in electricity demand are postulated via elimination of fossil fuel combustion in the transportation sector for LDV.

The scenario assumes that 100% of all fossil fuel combustion in the residential and commercial sector is eliminated and that the use of natural gas and liquid fuels is replaced by electricity, some generated onsite via solar (about 40% of the energy demand), the balance being generated at utility plants. Industrial emissions are reduced by curtailing

fossil fuel combustion overall by 75% and only using natural gas and #2 oil; coal is eliminated in favor of natural gas. As in the Deep Blue scenario, 8.4 MMT of the 13 MMT in emissions in the industrial sector are residual emissions from asphalt, petrochemical production, etc.

The significant increase in electricity demand is met largely with carbon-free sources: 35% from nuclear (including ~10-12 new plants), 35% from renewables (maximum hydroelectric, maximum on-shore wind, and 100,000 GWh of solar or other utility scale renewable such as offshore wind), and 17% from NGCC plants with 90% CCS. This scenario employs as much NGCC with CCS as is practical to meet overall emissions targets, thereby requiring a larger fraction (and level) of carbon-free sources. They are assumed to be met with new nuclear plants.

As with the Deep Blue scenario, this scenario relies on the use of low carbon-intensity bio-derived fuels (in-state ethanol) to supply the liquid fuel needed for non-electric miles in the LDV category, and on the use of biofuels in the aviation sector.

The Ultraviolet scenario estimates emission at 55MMT, a 78 percent reduction in GHG emissions below the 1990 level.

SERIOUS CHALLENGES POSED BY THE LOW-CARBON GOAL

The scenarios, presentations, and discussion at the January 5 workshop illuminated issues and challenges facing the Council. In particular three sectors – transportation, electricity generation, and buildings – emerged as particularly challenging and significant. At present, the transportation sector produces 34.3% of the state’s GHG inventory; electricity generation, 19.1%; residential uses, 14.6%; commercial uses, 10.6%. The “business as usual” (BAU) case for 2050 projects that the transportation sector will produce 35%; electricity generation, 23.1%; residential, 12.5%; commercial, 10.8%; and industrial, 6.7%.

The text below discusses the challenges those sectors present.

Serious Challenge: Transportation

Mobility is essential to social and economic welfare. By all measures, New York is one of the most mobile states in the nation. It has over 11 million licensed drivers, 10.5 million motor vehicles – virtually all of them operating on fossil fuel, and joined by similar vehicles that travel to New York from other states – and 113,000 miles of roads, along with 4,800 miles of railroads, 18 commercial airports, and 495 public use and private airports. Ensuring a safe, secure, reliable, efficient, low-carbon transportation system is vital to the state’s future. (See [Strategies for a New Age: New York State’s Master Transportation Plan for 2030.](#))

Today’s transportation systems are defined by technological, socioeconomic, land use, and public policy factors. Transportation demand is growing, and patterns of travel are changing and increasingly reliant on multiple, interdependent modes of transportation. Congestion in urban areas is growing, and transportation systems in these areas are bounded by the built environment. Over the next 40 years, the transportation system will have to support the same or greater levels of mobility while lowering emissions dramatically. And the importance of transportation security to national and economic security is expected to increase.

Over the past three decades, tremendous growth in the transportation sector and the decline in US oil production have made the US and New York increasingly dependent on foreign supplies of petroleum. Today, about 60% of the oil consumed in the US is imported. In New York, transportation accounts for about half of petroleum consumption, the equivalent of about 300 million barrels per year, or about 4% of the US total. As the potential for disruptions in world oil supply and production of refined petroleum products increases, so does the risk of disruption to the state’s transportation system. Given projected growth in demand for oil in emerging markets, notably China and India, the cost of oil and the reliability of supply are important risk factors to consider.

Within the transportation sector, road transport is the largest consumer of energy and the largest source of emissions. The major contributors to emissions are light duty vehicles (LDV), a category that includes automobiles, SUVs, motorcycles, and light trucks, and heavy duty vehicles (HDV), which includes trucks for road freight as well as buses. After road transportation, aviation is the next biggest contributor. Another important factor is the impact of the design and construction of the local built environment on mobility and patterns of use of available modes of transportation.

Addressing transportation requires a holistic look at all the factors that can improve efficiency as well as reduce emissions. In general, approaches to transportation examine (1) society's future mobility needs, (2) the technical efficiency of a given mode of transportation and the potential for improvements, (3) the effects of the operating environment, and (4) the mix of transportation modalities and potential systems performance improvements via changes in the mix of modalities.

Transportation and the built environment

The New York metropolitan area enjoys an extensive public transportation system that is well integrated into the region. Some 4.8 million passengers use public transportation on a daily basis. The high density of housing, proximity to public transportation, and its relative ease of use contribute to this high level. Aspects of the region have attributes of "compact, mixed-use development" – also known as "smart growth."

In all of the mitigation scenarios, a significant reduction in projected VMT level for 2050 (240 billion miles) is assumed. The assumption is that smart growth can promote greater reliance on public transportation and/or increase walking and bicycle travel. At the January 5 visioning workshop, success stories about smart growth in urban and suburban areas were recounted – notably for Arlington, Virginia, and Portland, Oregon. They offer models for New York's suburbs and for cities other than New York City; for example, the corridors in Long Island along the Long Island Railroad and major traffic arteries.

Over the 40-year horizon of the Climate Action Plan, many urban and suburban centers will very likely be rebuilt or redeveloped. This will create opportunities to reshape the state's transportation system and its use – if transportation planning and redevelopment efforts are approached holistically and use smart-growth practices. As redevelopment in urban and suburban areas occurs, more compact, mixed-use development that includes higher population and employment densities, competitive alternatives to automobile use such as pedestrian and bicycle paths, street networks that provide connectivity between destinations, and easy access to public transportation can all reduce residential and commercial energy use, GHG emissions, and VMT.

A recent and comprehensive [study](#) by the Transportation Research Board of the National Academies explores the impact of and correlation between driving behavior and the built environment. It concludes that compact, mixed-use development can reduce VMT by

differing means and amounts depending on where the development in a region occurs. The study reports that the literature suggests “that doubling residential density across a metropolitan area might reduce VMT by about 5-12%, and perhaps as much as 25% if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures.” It also notes that more study is needed to better understand the causal links between specific design elements in land use, transportation pathways, high density housing, employment centers, and other factors and reductions in VMT and increased use of public transportation.

To significantly reduce VMT would require changes in current practices and patterns of development in suburban areas. In home-rule states like New York, land use is largely a function of local governments, which can be reluctant to zone for higher-density housing because local residents often resist it. Statewide change would require that state-level policies be enhanced with incentives that encourage and support compact, mixed-use developments that would result in greater energy efficiency, increased use of public transportation, and reduced VMT and GHG emissions.

These efforts would be facilitated by communitywide design standards (the equivalent of LEED certification); the development of partnerships among State and local governments and private developers; tax incentives; coordinated State, federal, and local infrastructure investments; coordination with regional transportation authorities and operators; and rezoning to support appropriate transit development.

Light duty vehicles

In 2007 New York State residents drove over 140-billion VMT and consumed some 7.6 billion gallons of gasoline [EIA, Energy Consumption 2007], largely through the use of personal vehicles. As our mitigation scenarios reveal, significant emission reductions are possible in the transportation sector. The scenarios explore three alternative future vehicle fleets: one a mix of conventional, hybrid, and plug-in hybrid electric vehicles (PHEVs) (Yellow scenario); one dominated by hydrogen vehicles (Deep Blue); and one dominated by PHEVs (Ultraviolet). The latter two scenarios show that fuel switching will drive increased demand for electricity production, either for vehicle re-charging or electrolysis of steam for hydrogen production. Of course, emissions reductions would only be realized by the use of nearly carbon-free electricity sources such as renewables, nuclear, or natural gas or coal-fired plants with CCS.

What will it take for the US to realize 100% PHEV or 100% all-hydrogen powered cars on the road in 2050? Significant changes to automobile technology, of course. However, replacing New York’s entire fleet of automobiles will take time. The lifetime of a car is long; the mean lifetime is about 15 years: half the cars sold today will still be on the road in 15 years, and it will take about 25 years for 95% of the autos sold today to be retired. (See the ORNL [Transportation Energy Data Book](#) [2009 ORNL-6984]). Thus, to achieve a fleet

composed of 100% PHEV cars in 2050, 100% of the cars sold in 2025 and every year thereafter would have to be PHEVs. The same case applies to hydrogen-fueled cars.

Another reason why changing the entire fleet will take time is that it takes time for transportation equipment and automobile manufacturers to adopt new technology and integrate it into their product lines and manufacturing processes. At present, automobile models undergo a complete redesign approximately once every 8 years, and new designs are locked in about 2 years in advance. Thus, it could take from 5-10 years for a new automobile design to be brought to market, and another 25 years to completely change over the fleet.

For PHEVs, this penetration rate is more aggressive than what experts are predicting. For example, a recent study by the National Academy of Sciences (NAS), [Transitions to Alternative Transportation Technologies – Plug-in Hybrid Electric Vehicles](#), concluded that PHEVs are “unlikely to achieve cost effectiveness before 2040 at gasoline prices below \$4.00 per gallon,” given the higher costs when compared to conventional vehicles. Further, the NAS PHEV study concluded that “at a maximum practical rate, as many as 40 million PHEVs could be on the road by 2030, but various factors (e.g., high cost of batteries, modest gasoline savings, limited availability of places to plug in, competition from other vehicles, etc.) are likely to keep the number low.”

PHEVs are scheduled to enter the US market in the 2011-2013 timeframe. They will have an all-electric range of ~30-60 miles. For mass-market penetration, a greater all-electric range of around 100 miles or more would be needed – underscoring the need to develop higher performance battery technologies. Costs must come down, too. Drivers include electronic controls, drive trains, and batteries. Lithium-ion battery technology has been developing rapidly, though costs are still high and, according to the NAS study, expected to decline only by about 35% by 2020. Further technology development will likely reduce costs below these levels, as well as increase storage density and reliability, possibly by using alternative chemistries to lithium ion batteries.

Other notable barriers include the need for suitable charging stations or battery exchange facilities and consumer acceptance of PHEVs, especially if PHEVs cost more than similar functioning hybrid electric vehicles and require daily (or more frequent) recharging. Adoption of PHEVs by large vehicle fleets, such as federal, state, and local government fleets, may be an appropriate first step to increase adoption, if costs are reasonable.

The Deep Blue scenario explores the potential impact of fuel switching from gasoline to hydrogen for vehicles. Hydrogen vehicle technologies largely follow two paths: direct burning of hydrogen in a suitably modified internal combustion (IC) engine or use of electrochemical fuel cells (proton-membrane exchange fuel cell [PMEFC]) which, in turn, drives an electric motor. Hybrids of electric and combustion processes are also conceivable – PMEFC with batteries, for example. It is important to note that hydrogen-based ICs and PMEFCs have applications in local point-of-use generation of electricity. It’s conceivable that ICs and PMEFCs could be used for hot water, lighting, and heating in residential and

commercial applications, as well. Studies of the energy efficiency of hydrogen (such as the National Academies of Science's [The Hydrogen Economy](#)) find that the hydrogen vehicles would not substantially reduce total energy use per mile driven (the "wheels to wheels" energy per mile driven) unless the hydrogen were produced from wind or solar power.

The Deep Blue scenario relies on nuclear power with high temperature electrolysis of water to produce hydrogen, with electricity and heat generated from a nuclear reactor. Alternate approaches include steam reforming of methane using process heat provided by a very-high temperature nuclear reactor, or through a thermochemical cycles, such as the sulfur iodine process. Steam reforming of methane is widely used in industry to make hydrogen today, and this [process](#) is well established. Carbon release from steam reforming of methane would compromise emissions gains through the use of nuclear power and is a potential showstopper, though carbon capture is not inconceivable.

Beyond nuclear-based approaches that rely on steam reforming, several technologies are envisioned for large-scale or central generation of hydrogen. Coal and natural gas integrated gasification combined cycle (IGCC) or natural gas combined cycle (NGCC) plants could also serve as a heat source for steam reforming of methane – and for much smaller hydrogen generation scales, solar PV or wind could be used for electrolysis. Of these sources, only nuclear and renewable-based hydrogen production have a zero-carbon footprint, and with the advent of carbon capture and storage (CCS) technologies, central-station hydrogen production from coal or natural gas plants would have a carbon footprint five to ten times smaller than that of gasoline. The price of hydrogen is highly dependent on the way hydrogen would be produced and associated emissions from the generating source. Thus, today, nuclear-based, as well as NGCC or IGCC with CCS, appear to be cost-competitive with gasoline, while the higher cost of electricity generated by renewable sources is two to five times more expensive.

At best, hydrogen represents a long-term option. Significant technological and infrastructure breakthroughs are needed before it's considered viable. Significant improvement in the energy density of hydrogen storage, reductions in fuel cell costs, increased lifetime and reliability, as well as cost reductions in hydrogen production are needed. Safety is also an important factor. Initially, transportation and distribution of hydrogen would entail transport by truck to regional distribution centers, using compressed gas cylinders. Over time, the use of hydrogen to fuel vehicles would require construction of infrastructure such as pipelines and fueling stations.

To overcome some of the barriers to adoption of hydrogen fuel for PHEVs, New York State would have to work with other states and the federal government to develop requirements that drive the market toward new vehicle technologies. In the meantime, fuel efficiencies and carbon reductions will be realized through improvements to conventional vehicle technologies and greater market penetration of hybrid electric vehicles.

Heavy duty vehicles

Trucks carry the bulk of freight transport. In New York State, 90 percent of commodities by weight are moved by truck, while only 3 percent are moved by rail - a more efficient and less GHG-intensive mode. Freight traffic is expected to grow significantly, with a concomitant growth in VMT. More-efficient, less GHG-intensive modes of transport are clearly needed. In general, there are two ways to reduce HDV emissions: directly reducing truck emissions, and shifting freight from trucks to more efficient and less GHG-intensive modes.

The factors that affect truck emissions and efficiency include (1) the nature of the fleet mix (the size of the trucks), (2) the fuel-efficiency of the trucks, (3) the operating environment (built environment, road conditions, traffic and congestion, etc.), (4) how trucks are operated (speed and idling), (5) the nature of the cargo and truck loading (weight, density, containerized vs. open-bed freight, etc.).

The mix of trucks and their patterns of use are extremely heterogeneous. Efforts to reduce emissions should focus on the largest fuel consumers: tractor-trailers and straight trucks. Tractor-trailer efficiency improvements should start with retrofits to reduce truck frame drag. Estimates indicate that truck retrofit packages (such as aero-cab, front flaring, side skirts, rear tail flaring, low rolling-resistance tires) can improve truck efficiency on the order of 5-10%. Retrofit packages can be readily adopted for existing fleets. (The Union of Concerned Scientists offers information on [green trucks](#). Scroll down that web page for a link to a study by the technology firm TIAX, [Heavy-Duty Truck Retrofit Technology: Assessment and Regulatory Approach](#).)

In addition, future truck fleets will rely on advanced truck engine designs, such as hybrid-electric engines, with an estimated efficiency increase of 7-9%. Adoption of new engine technologies will take time, as the market is conservative and fleet turnover is much slower than for LDVs: the median lifetime of a HDV is well over 20 years. This implies that the penetration of a new technology will take significantly longer in the HDV market than in the LDV market. Consideration should be given to policies that may speed adoption of new technologies.

Biodiesel is the first advanced biofuel in large-scale commercial production. Biodiesel produced from domestic soybean oil is assumed by the EPA to reduce GHG emissions by 57% compared to petroleum diesel fuel, and the EPA's lifecycle analysis recognizes that the GHG reduction could be as high as 85%. (See <http://www.epa.gov/otaq/renewablefuels/420f10006.pdf>.) In the US, biodiesel production is now expanding rapidly (see http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Graph_Slide.pdf). In 2005, production was 75 million gallons; in 2007, 450 million gallons; in 2008, approximately 700 million gallons. By 2011, 1 billion gallons of biodiesel will be produced. An assessment of the resource available to produce biodiesel indicates that feedstock available today could produce more than 1.7 billion gallons per year.

Intermodal

Convenience and cost are the key factors that determine the mode of transportation for the shipment and distribution of goods. In New York State, the predominant method for transport of freight is by truck, with up to 90% by weight shipped by truck. Truck transportation is the most energy and GHG intensive modes of the movement of freight. A key challenge to reducing GHG emissions in the transportation sector is then to reduce emissions from truck transport of freight. This can be most readily accomplished by reducing GHG emissions from trucks and/or shifting freight to other modes of transport with lower emissions. New York State will have to investigate policy options to bring about modal shifts. These would include:

- Financial assistance to develop more efficient organization of supply-chains, including advanced logistics capabilities and optimal positioning of trans-shipment points and distribution centers.
- Increasing fuel and economy standards for trucks, speed limit reduction/enforcement, and development of anti-idling policies and electrification of rest-stops.
- The development and adoption of advanced technologies, particularly the development of no or low net-carbon bio-diesel fuels and waste heat recovery systems to power air conditioning/electronics.
- Reducing congestion by increasing non-truck modes of transportation; provide incentives and build infrastructure to encourage switching from truck to rail or water transport.

Aviation

Emissions reductions in the aviation sector can come from advances in three areas: improved efficiency through advances in technology, development, and adoption of suitable bio-derived fuels, and improvements to operations and air traffic management.

Significant emissions reductions in the aviation system will come from new composite materials that result in airframe weight reductions, as well as improvements to engine design. For example, as much as 50% of the primary structure of the new Boeing [Dreamliner](#) is made from advanced composite materials. Coupled with advanced engine designs, this will increase fuel efficiency as much as 20% over similar sized aircraft, while permitting air speeds characteristic of the fastest wide-bodies, mach 0.85.

The National Academies' [Airports Cooperative Research Program](#) is examining alternatives to fossil fuels, as is a [coalition](#) that includes the Federal Aviation Administration. [Industry interest](#) in the subject is growing. Currently, new biofuels – “biojet” are being developed for the military. This represents a significant opportunity for reduction of net carbon emissions

from the aviation sector if a sufficient supply of biofuels can be developed for wide-scale adoption and use.

Changes to [air traffic management](#) are expected to lead to ~10% reductions in fuel use, through better management of holding patterns, more efficient take-off and landing trajectories, and minimization of suboptimal routes. Switching modes of travel can reduce emissions, too. Many short-distance flights could be replaced by inter-city high-speed rail; for example, between New York City and Albany, as well as Buffalo.

Serious Challenge: Electricity Supply

Electricity generation is currently among the largest sources of GHG emissions and is projected to remain so under the BAU case. New York's current electricity generation system is a diverse mix of primary energy sources, with about 53% of net generated electricity coming from fossil fuel-fired electric generating units. With a diverse resource mix and a solid base in renewable energy, the state's electric sector is expected to contribute approximately 75.5 million tons of CO₂e to the GHG emissions inventory in 2050

The electricity sector presents a serious challenge for a set of reasons:

- *All mitigation scenarios place increased demand on the electricity sector.*

All three 80x50 scenarios assume total electricity demand in excess of 400,000 GWh, a 50% increase over the BAU case. This is typical of mitigation strategies – for example, see the results of the [Global Technology Strategy Project](#). The reasons are several. The most important is that it is much easier and more cost effective to manage any residual carbon emissions at a central electric generation facility than in highly distributed sources like vehicles or buildings. In the 80x50 scenarios, energy demand is driven to electricity by the almost complete conversion of the building sector to electricity, the substitution of electricity for liquid fossil fuels as an energy carrier in the transportation sector (most notably in the Yellow and Ultraviolet scenarios), and a general shift from fossil fuels to electricity in the industrial sector.

The flexibility of electricity as an energy carrier has led to continued growth in its use. The electricity sector has been well studied, and many technological improvements are made every year. These improvements are quite important: efficiency improvements in the conversion of energy stored in fossil fuels to electricity has a direct impact on the capital cost of all electricity generation resources. Even more important, improvements in the efficiency of end-uses of electrical energy reduce total demand for electricity. The scenarios for each of the major end-uses begin with an assumption of large improvements in end-use efficiency, ranging from 20-30%. Generally, it's expected that the electric generation sector could be decarbonized more easily than distributed uses of energy could be.

- *Renewable resources within the state are not adequate to meet the challenge.*

The major renewable sources of electric power that are carbon free are wind, solar, and hydropower. With the exception of large hydroelectric facilities, these resources are distributed: they collect a local resource. Moreover, in comparison with, for example, a large thermal electric facility like coal or nuclear, they generate far less energy per unit of land. The Yellow scenario includes practically all of the available renewable energy resources in the state, and it includes only resources from within the state. The renewables are over and above the renewable sources assumed to be integrated with buildings.

Wind is a relatively mature technology, and it's relatively easy to estimate how much wind energy is available. The current analysis includes both on-shore and off-shore wind resources. On-shore wind deployment is increasing around the world, but every deployment faces challenges. The first is the actual siting of the turbines, which is often resisted locally for aesthetic and environmental reasons. Second, wind is an intermittent resource and places special demands on the grid, as discussed below. The scenarios are fairly optimistic about success in siting turbines, and they assume wind power's straightforward integration into the grid (as estimated in a [2003 study](#)). They also assume that the current 873 GWh of wind can be expanded to 42,000 GWh by 2050, meeting just over 10% of total projected demand.

Solar is a far less mature technology in terms of both efficiency of conversion and experience with actual installation. The Yellow scenario assumes that 100,000 GWh of demand will be met by grid-installed solar (~25% of 2050 demand); currently in New York the value is zero. This makes the Yellow scenario quite aggressive in several regards. First, this amount of solar energy requires a large amount of land, probably far more than is commonly assumed. For the current generation of solar PV sited in New York, it would take about 1% of the area of New York to generate 100,000 GWh of electricity. Second, it requires a massive improvement in the ability to manufacture photovoltaic (PV) devices. Most current solar technology is based on silicon, and despite large increases in PV cell production, global consumption of silicon for solar applications only recently passed consumption of silicon for semiconductor devices such as computers. Without low-cost, mass production of solar cells on the scale of products like paper or steel, large-scale deployment of solar energy is unlikely. Finally, solar, like wind, is an intermittent resource with special requirement for integration with the grid.

New York has significant hydropower resources, thanks to Niagara/Horseshoe Falls and the St. Lawrence Seaway. Further upgrades and expansions, with a small component of new dams, could significantly increase electric output to the grid and reduce GHG emissions. The Yellow scenario assumes that 10,300 GWh of hydropower will be added to the 25,500 GWh, satisfying nearly 10% of projected 2050 electricity demand.

In summary, the relatively aggressive goals included in the Yellow scenario, which are incorporated in the other two scenarios, meet less than 50% of projected 2050 demand, and indeed in the future they may not be met. But other sources of renewable energy might improve the prospects of success. The largest is probably offshore wind. In addition, full-scale testing of kinetic, in-river hydropower applications is under way in the East River and St. Lawrence River. These projects and maximum build-out were not considered in our analysis, but they could add slightly to the total hydropower package of emission reduction technologies and strategies.

- *Low carbon-emitting central generation options all entail serious issues.*

The discussion of renewable electrical energy options above underscores the fact that demand for central generation of electricity will continue. This demand must be met with low-carbon or no-carbon conversion technologies. Currently in New York, large central generation relies on fossil fuel and 42,500 GWh of nuclear power. Options considered in detail in the scenarios are expanded use of nuclear generation and use of fossil fuels with carbon capture and storage (CCS).

The future of nuclear power generation is uncertain, but nuclear power could satisfy a good portion of a future electricity demand or hydrogen production demand (as discussed above). All of the scenarios assume a continuation of the existing level of nuclear power generation; each takes a different approach to nuclear. The Yellow scenario meets the low-carbon generation option without expanding the current nuclear fleet. The Deep Blue scenario assumes expansion of nuclear power generation by 2 new plants that would generate 25,000 GWh, not counting the additional reactors required for hydrogen generation. The Ultraviolet scenario expands the nuclear supply of electric power by 118,000 GWh, meeting a total of 40% of 2050 electric demand with nuclear power, comparable to the amount planned by Japan.

The scenarios do not speak to the resolution of specific issues associated with nuclear power. Expanding nuclear power will require substantial capital investments and federal loan guarantees. It would require investment in scientific research into and technological advances in alternative fuel cycles and nuclear waste management. It would require public acceptance of license renewals for existing nuclear power plants, expansion of current plants, and siting of new plants.

Fossil fuel combustion with CCS is a significant component of all three scenarios, accounting for 190,000 GWh of energy in the Yellow scenario, 170,000 GWh in Deep Blue, and 70,000 GWh in Ultraviolet. Both coal (IGCC) and natural gas are included in differing amounts in the scenarios. While important in implementation, the fuel choice is non-substantive in comparison with other challenges associated with CCS. They include efficiency of capture and storage, establishment of storage reservoirs, and construction of infrastructure to transport CO₂ from its point of generation to the point of storage. Notably, CCS is not yet commercially available and in fact has not yet been successfully

demonstrated on a commercial scale. Moreover, the regulatory scheme that would govern it remains to be defined, and the capacity for large scale CCS in New York is not presently known.

Probably the most important CCS challenge is efficiency of capture and storage. The scenarios assume a capture efficiency of 90%, with the electricity sector contributing 24, 13, and 10 MMT CO₂e for the Yellow, Deep Blue, and Ultraviolet scenarios respectively. For the latter two scenarios, which do meet the 80x50 goal, CCS still produces 20-25% of total emissions. The improvement of CCS technology to, for example, 99% would significantly reduce emissions.

Storage and transport of CO₂ present closely related issues. The capacity to store CO₂ is not homogeneously distributed throughout the state. Further, little is yet known about the suitability and capacity of those sites to store CO₂. There will be a trade-off between siting of generation sources and siting storage facilities. Certainly, concentrating emissions sources near large-capacity storage reservoirs would simplify implementation and reduce costs. But it could also further increase the burden on the grid. [NYSERDA's studies](#) of New York's potential for CCS are important to defining the long-term potential.

Finally, it should be noted that as 2050 approaches, nuclear fusion may become a viable zero-carbon source of electricity. The scenarios assume it won't be sufficiently well developed to meet energy demand in 2050, but as the State looks beyond its 2050 target to continuing emissions reductions, this technology may be important. Decisions made between now and 2050 can impact its availability in the long run.

- *Infrastructure for electricity transmission and distribution must evolve to meet demand and other services the grid must provide.*

Fortunately, growing demand for electricity is accompanied by substantial research into and development and deployment of new technologies, which are shaping the grid of the 21st century – and at a time when capital improvements to New York's aging grid infrastructure are needed. The smart grid will deliver substantial benefits: greater reliability, enhanced security, "smarter" use of information technology, integration of renewable power generation, better storage technology, and sophisticated demand-management strategies. The ability to manage demand can yield another benefit: avoidance of the huge costs of building more power-generating plants.

The 80x50 scenarios assume three significant demands on the grid. One is the need for increased capacity to carry energy. The capacity increases can be met in two ways. The most straightforward is to install higher-capacity transmissions lines and to increase capacity through upgrades to substations, transformers, and distribution lines. Since all three scenarios call for a 50% improvement in transmission and distribution (T&D) efficiency (which contributes as much to emission reductions as all of the hydro

enhancements), the upgrades will both increase capacity and reduce T&D losses. Another method is changing from conventional T&D lines to high-temperature superconductors. This technology both increases capacity and decreases losses, and it's already employed in two locations in New York State. However, it's complex to manufacture, and manufacturing capabilities must be radically scaled up and costs shrunk before it can be widely deployed.

The second demand on the grid arises from reliance on large amounts of solar and wind: their intermittency must be managed and compensated for. As intermittent loads grow, this becomes a larger and larger problem. In general, the approach been viewed as a question of "what do you do when the sun goes down, or the wind stops blowing?" This implies the availability of a backup energy resource. Because baseload power from thermal resources (nuclear and fossil with CCS) performs best if it operates continuously, increasingly the view is that energy storage might be the best option for intermittent sources.

Hydro resources have some limited storage capacity, allowing their output to be increased when demand grows. However, without "high" dams like those in western US states, this storage is limited. NYSERDA is studying the potential of below-ground compressed air storage potential in New York. The next step is to introduce storage technology, such as batteries, or in the long run, superconducting magnetic energy storage (SMES). This kind of storage has the added value of serving as a convenient means of helping to manage transients in the system, as well. Managing storage to compensate for intermittency will be greatly enhanced by incorporating information technology into the smart grid.

The smart grid also facilitates another strategy for managing intermittency: demand response, in which loss of generation is compensated for by a sophisticated demand-reduction strategy that targets flexible and non-essential loads, shutting them off for a short period of time. These loads can be at the commercial and industrial level, but recent and ongoing demonstrations also show success in the residential sector through use of smart meters and smart appliances.

Finally, the changing mix of end uses on the demand side will alter the temporal demand for electricity on time scales ranging from daily to seasonal. In general, this is a design and load-dispatch problem. What generation resources do you bring on, when, to minimize the cost of generation? To satisfy peaks in demand with the more-expensive generation resources and, through pricing strategies, encourage end-users to not use resources during peak demand periods? Switching of peaks among seasons, from summer peaking to winter peaking, for example, can create resource mismatches for resources that may have a strong seasonal variability, such as hydro and solar.

The scenarios assume the largest new demand will come through vehicle electrification. Studies have shown that smart electronics in, for example, PHEVs can manage that demand to fill in periods of otherwise lower demand. This allows baseload plants to

operate more or less continuously, with consequent greater efficiency. Charging the PHEV “appliance” can also become part of the demand-response network used to manage intermittency – another benefit of the emerging smart grid.

Challenge: The Building Sector – Residential & Commercial

A critical challenge to reaching the 80x50 goal is in the performance of residential and commercial buildings. Reaching mid-century GHG reduction goals will require that buildings function with minimal or no net-energy input (input from the electric grid or from onsite use of high-carbon fuels). New residential, commercial and industrial building systems will need to significantly reduce, and eventually eliminate, onsite fossil fuel combustion for space heating, water heating, cooking, and other needs, and supply electricity through onsite generation from low-carbon energy sources.

The strategy suggested in this vision requires that buildings function with minimal or no net-energy input from onsite use of high-carbon fuels and that to the extent possible their energy demand not be shifted to the grid.. These new residential, commercial and industrial building systems will reduce, and eventually eliminate, onsite fossil fuel combustion for space heating, water heating, cooking, and other needs, and will supply electricity through onsite generation from low-carbon energy sources.

The relationship of the building sector to other sectors is a critical aspect of the 80x50 challenge. These relationships fall within four broad areas:

- End uses: Residential and commercial buildings represent a growing sector of energy demand. This demand is a central part of the standard of living we enjoy. An example is the growing use of personal electronics in residences and the development of large datacenters that support the new internet enabled economy, particularly the global financial industry based in New York. The critical first step in any carbon reduction strategy will be increasing the end use efficiency of the equipment and devices within structures. Reductions of 30% in each electricity and natural gas use is rather straightforward through the adoption of more efficient end-use technologies, such as more efficient lighting, space heating/cooling, water heating, computers, and televisions – as well as through the use of modern controls.
- Structures – A substantial component of the energy demand in the buildings sector is for space conditioning. End use efficiency has an important impact on this demand, particularly in the commercial sector where the cooling demand created by waste heat from devices and equipment. In New York the challenge of structures is exacerbated by the fact that much of the building infrastructure already exists. This will lead to important challenges in improvements of the performance of building

envelopes and the creation of cost effective retro-fit options for key building systems such as windows and increased sealing and insulation.

- Distributed generation – One real option for building is the promise of distributed generation. The use of both photovoltaics and passive solar heating as well as the exploitation of geothermal resources through such technologies as ground source heat pumps offers real promise. The greater the contribution of these technologies to both efficiency and meeting electric demand the less the buildings sector will contribute demand to the already growing burden on the grid. There are many policies options that can help reduce the capital costs barrier could be strong enablers of broader adoption of distributed generation technologies in residential and commercial sectors.
- Communities and the promise of smart growth – Probably the most important trend will be the increased view of the buildings sector as a component of communities. Many of the elements above are even more valuable when one considers collections of structures and seeks to manage energy for these aggregations. Distributed generation for communities can include wind and local biomass conversion for heat and power. The community can become part of a micro-grid that not only effectively manages the electric demand of the community but also can be the basis of using the community as a dispatchable demand response resource for the wider grid. Finally, if the communities take on the “smart growth” approach both in new construction but also in re-development, the communities themselves can have appositive impact on other sectors, most notably transportation.

There has been extensive work on energy efficiency in buildings, done by the [World Business Council on Sustainable Development](#), [the National Academy of Science](#), the [Pew Center on Climate Change](#), and [Lawrence Berkely National Laboratory](#), which offer key data and insights to the energy savings potential. A difficulty in comparing the energy efficiency potential across studies is the variation in methodologies and measures within each of them. However, there are some common themes worth noting.

BOTTOM-LINE ISSUES AND CONSIDERATIONS

The scenarios that inform the visioning process can be further manipulated to yield more insights into interrelationships among mitigation strategies for various sectors. But even at present, and the benefit of insights and knowledge gained at the January 5 visioning workshop and from yet other sources, it's clear that major decisions are necessary to achieve the 80x50 goal.

Many of those decisions must be made sooner rather than later, as they affect long-lead-time matters such as infrastructure investments and research and development strategies that can help or hinder progress. Moreover, the early adoption of some measures won't preclude later adoption of others. Thus, identifying pivotal future decisions and sequencing them becomes a serious challenge in its own right.

The text below discusses issues that follow from the discussion of serious challenges above, and that emerged from the visioning process and other sources. Some concern single economic sectors; some span two or more. While it can be difficult to differentiate technical issues from policy issues, we've tried: the points immediately below are primarily technical in nature; policy considerations follow.

Technical considerations

- Gains in energy efficiency are critical to achieving a low-carbon future. The scenarios don't specify mechanisms, technologies, or practices necessary to achieve these gains, but their importance is clear.
- Very soon, a risk assessment table for critical technologies, such as CCS, nuclear, and solar, should to be developed. This table would highlight the barriers to and compare the types of uncertainty associated with each technology, facilitating the identification of both policy measures and research investments.
- Electrification is an essential strategy, too, and a move to electrification is consistent with the energy needs of a 21st-century economy based on information technology, biotechnology and nanotechnology. If New York's demand for electricity nearly doubles by 2050, a number of issues arise. For one thing, electrification transcends selecting non-carbon emitting central generation technologies and arranging for their siting and financing. Demand on transmission and distribution systems will increase, too. This means that ongoing planning for the smart grid and associated technologies must be part of the Climate Action Plan strategy.

And growing demand will alter not only the amount of electricity needed but when demand peaks, on timescales ranging from daily to annually. How the load duration curve, one measure of changing demand, is managed will be an important part of the smart grid. This may include the use of storage to facilitate handling of larger quantities

of intermittent renewable resources, and the use of active demand management technologies like demand response.

- Electrification of buildings could create a stranded asset in the gas distribution system. The existing infrastructure for gas and its continued expansion may create a structural barrier to the goal of reducing highly distributed point sources of GHG emissions. On the other hand, pipelines moving CO₂ from gas combustion facilities to storage reservoirs may be co-located along rights of way, provided they are appropriately located.
- All scenarios call for the phase-out of fossil fuel generation that free-vents carbon to the atmosphere. The schedule for retiring or converting existing facilities thus becomes an issue.
- Similarly, existing nuclear power plants are on the critical path for a future that continues to rely on nuclear power. These plants would have to be replaced or re-licensed. If relicensed, it would probably be for a maximum of 20 years; they'd then be replaced.
- Nuclear and/or fossil fuel combustion with CCS, which is largely undemonstrated, are important for decarbonization of centrally generated power. Both require long lead times and large capital outlays. CCS also requires significant infrastructure for storage, which will include site selection and certification as well as some pipeline infrastructure. The regulatory scheme that would govern siting and operations of CCS facilities and storage locations remains to be defined.
- The transformation to a hydrogen economy would require a new infrastructure for producing and delivering hydrogen to consumers. The development of gas-cooled, high-temperature nuclear reactors to produce hydrogen would require new plant designs, which would require licensure. Safety regulations for transportation and storage of hydrogen would also be needed.
- In our scenarios we've included some technologies that are emerging but not yet commercial, such as CCS. Others are unproven, such as large energy storage. We omitted nuclear fusion, an unproven technology, and direct air capture of carbon dioxide, which is speculative at this time. These all have theoretical potential to help achieve the 80x50 goal, but the timeline for making changes requires technologies that are in development today, and ready for deployment at scale within approximately a decade. The current [international roadmap](#) for fusion would have the first demonstration reactor online in about 2040.
- The scenarios assume complete success; for example, total conversion of the building sector to electricity, or to net-zero carbon emissions. Inevitably, there will be "leakage," which will place further limitations on emissions from other sectors or technologies.

- Renewable resources play a major role in all three scenarios. But even with expected gains in renewable energy technology efficiencies, the state's renewable resources can't meet all of projected future energy needs. And, distributed resources used on a large scale would require large tracts of land for solar arrays, wind farms, and biomass cropping. The scenarios assume all renewable resources would come from within the state. This is consistent with the State's desire to develop its own resource and energy industry. But out-of-state renewable resources could be used, too, and perhaps in some cases more cheaply. Opening the market could take pressure off in-state only resources.
- Sustainable biomass is a limited resource. What's the best allocation for its use? Should it be used for transportation (as in our scenarios), to heat buildings, or for power with CCS, which could create a carbon sink?
- The grid-installed solar electric assumption in the scenarios is quite optimistic and may not be met without significant energy conversion improvements in photovoltaic panels and systems. Distributed solar awaits gains in scalability, reductions in cost, and the creation of large-scale installation capabilities. The scenarios don't include some renewable technologies that may be fungible and that could help reduce emissions, such as geothermal and hydrokinetic energy sources.
- The transportation sector is an extremely large, diffuse source of GHG emissions. All of the scenarios largely call for eliminating gasoline and diesel as energy carriers and replacing them with bio-fuels, hydrogen, or electricity. The sector is diverse, with each of the subsectors – light duty vehicles (LDV), heavy duty vehicles (HDV), mass transit, and aviation – having its own special needs. Key issues include these:
 - Transportation options create an infrastructure demand that must be accounted for in planning. The current network of fueling stations for LDV and HDV is pervasive, with one or more fueling station in virtually every community and neighborhood in the state. Pushing vehicles to electricity adds demand to the distribution system, while a hydrogen-based vehicle system would necessitate replacement of key components of this extensive refueling network.
 - The specifics of how to reduce VMT aren't addressed in the scenarios. They're important: e.g., reducing VMT means increased demand on and expansion of mass transit, as well as potential impacts on community design, development, and redevelopment.
 - Significant improvements in vehicle fuel efficiency are important to the mitigation scenarios. Whether national standards will be sufficient to drive this change is questionable.
- The state's residential and commercial sectors are a major source of emissions, and the scenarios call for substantial improvements in energy efficiency and the source of energy used for space conditioning, hot water, and cooking. At the January

workshop, the point was made that many building professionals have little concept of how much buildings contribute to GHG emissions, and how little it costs to mitigate them. New York City's new [Green Codes](#), a major effort commissioned by the Mayor and City Council Speaker, may offer a useful guide for other cities in the state, for starters.

But even if all building owners, managers, and tenants were committed to greening the existing building stock, the workforce needed to install energy retrofits may not be adequate to the job: training may be required, along with financing schemes that facilitate retrofits.

- All three scenarios assume use of distributed renewable energy in the building sector. This resource is over and above transmission-connected resources accounted for in the electricity sector. The Deep Blue and Ultraviolet scenarios call for the residential sector and commercial sector to be zero emissions, not net-zero. If the strategy evolves to a net-zero standard, other emissions not accounted for in the scenarios will have to be offset.
- Serious methodological questions must be addressed. For example, how well understood are interconnections among complex physical systems—the networks of energy inputs and feedback loops—that drive emissions? That link energy use and water use? Should estimates of GHG emissions include embedded energy, which produces emissions beyond the state's borders? How far should lifecycle analyses go?
- With a goal of 51 MMT CO₂e, even small sources of emissions become important. Emissions reductions strategies for several sources (e.g. asphalt production, SF₆ leakage, etc.) are not immediately clear. Work is needed to develop strategies for management of emissions from all sources.
- *Interdependencies.* The interdependencies, and consequent vulnerabilities, of transportation, water, energy, and communication systems have direct consequences for system performance and thus for climate change adaptation and mitigation. System managers and operators must be helped to understand and manage those interdependencies.

Policy considerations

- *Incipient policy conflicts and synergies.* The Climate Action Plan has pervasive ramifications for the state's economy and social fabric. Many existing State policies may facilitate or hinder achievement of the 80x50 goal. Policies made by other states and the federal government can affect New York's ability to pursue its chosen path. For example interstate commerce (tourism, freight, and aviation) is shaped by federal policy. Large-scale renewable energy involves significant land-use choices,

for siting of wind and solar facilities and use of biomass resources; local choices and policies may affect the State's ability to meet its renewables goals.

- *Policy gaps.* What regulatory scheme will be required to cover the siting for CCS facilities, pipelines, and storage sites, and the permitting of CCS operations? For gas-cooled, high-temperature nuclear reactors that would produce hydrogen? For new technologies yet to emerge? Designing and implementing regulatory "infrastructure," so to speak, might be no small undertaking in its own right.
- *The need for partnering.* Related to policy conflicts and synergies is the great need for partnering among all levels of government and between the public and private sectors, with regional collaboration being a point strongly urged at the January 5 workshop. The inclusiveness and openness already demonstrated by the NYS Climate Action Council and the State's many other climate and energy initiatives, including the State's aggressive partnering with local governments through the [Climate Smart Community Pledge](#), augurs well for this. Obviously, close partnering with the business community will remain a long-term necessity.
- *Long-term consequences of near-term decisions, and lack of decisions.* Decisions made, and not made, about matters that require long lead times, such as major infrastructure projects, and that have long-term consequences, such as land-use policy and a commitment to CCS, cast long shadows into the future. Whatever the choice of low-carbon sources of electricity (CCS, nuclear, solar) and of energy carrier for transportation (electricity or hydrogen), the electricity sector *must* plan for the expansion of the grid and improvement of transmission and distribution. Some early actions, such as improving energy efficiency, have value regardless of other choices made; others may have value only in relation to specific choices of technology, such as development of CCS infrastructure. It's important to remember that achieving a low-carbon future requires a portfolio of actions, and that "easy" decisions aren't substitutes for hard ones.
- *The rate at which policies drive change matters to success.* But this important factor is difficult to manage. The Climate Action Council is working in a field in motion, as technologies evolve, economic conditions change, and other parties, including the federal government, make decisions that have consequences for New York.
- *Stranded capital investments.* Practically all energy-related technologies require both infrastructure and capital investment from the private sector, and those investments are generally large. If they are foreclosed because of decisions that support the 80x50 goal before they've delivered a full return on investment or reached the end of their useful lifetimes, the result will be stranded capital investments – both a major hidden cost of carbon mitigation and a source of resistance to future change.
- *Investments by the State.* The current performance of many technologies assumed by the mitigation scenarios – such as PV, offshore wind, large-capacity/low-cost

batteries, PHEVs, CCS, zero-energy commercial buildings and LEDs – is inadequate to meet the 80x50 goal. Those technologies will require investment to boost performance. Sources like DOE-National Lab Roadmaps and the National Academies' study, [America's Energy Future](#), identify step-function improvements in technology and major investments in infrastructure needed to achieve a low-carbon economy.

- *Motivating change.* The scenarios make no explicit assumptions about individual behavior. How to motivate individuals to modify their energy consumption and patterns of use, drew considerable interest at the January workshop, and warrants the attention the State Climate Action Council.

CODA

Insidiously, carbon emissions are cumulative: they persist in the atmosphere for up to thousands of years. This means that as levels of emissions grow, reducing them to levels deemed acceptable becomes ever harder. And because New York is already more energy-efficient than most states, reducing emissions from what is already a low baseline is harder, still.

Against this physical reality, the momentum of *business as usual* is not to be underestimated: it's one of the most powerful forces in the world. And yet, the nature of *business as usual* continually evolves. The "installed base" of current energy technologies represents trillions of dollars in sunk costs and powerful special interests. Fossil fuels are cheap, abundant, and convenient. Options for scaling up alternatives to them, affordably, are not yet in hand. Yet history tells us that technologies, and markets, continue to change. The brutal realities of fiscal deficits are certain to constrain important efforts to achieve the 80x50 goal. And yet they also make the very real economic opportunities generated by that goal even more compelling.

Notably, the assets and advantages that the State enjoys can be game-changers, too. Executive Order 24 is soundly and sensibly conceived. The Climate Action Council's approach to its task is exemplary. It enjoys the benefit of committed top-down leadership; many motivated state employees who possess technical expertise, policy savvy, and insight into how government and the political system work; a broad-spectrum approach that engages a large number of committed stakeholders in the NGO and private sectors; and a deep commitment to achieving environmental justice.

Crucially, the Council is rapidly gaining insight into the staggering magnitude of the challenge it has been tasked to address and the nature of the strategies it can employ.

Over coming decades, New Yorkers – long celebrated for being tough, resourceful, and creative – may well prove to be the equal of the 80x50 challenge. Every megaton of GHG emissions avoided will be a gain, and the societal and economic transformation achieved in vigorous pursuit of sustainability will create a future for our children and grandchildren and generations beyond that is *better* than the present we inhabit.

APPENDIX A

Supplemental Information on Methodology & Data Sources for the Baseline Forecast of Energy Demand and the “Business as Usual” Case

The input to the macro coupled-sector modeling is the baseline projection for energy demand by sector and fuel type in 2050. These values were estimated by a constant growth (% per year) extension of the modeling conducted in the development of the [New York State Greenhouse Gas Emissions Inventory and Forecast](#) for the [2009 State Energy Plan](#), which estimated the GHG emissions by sector and fuel type to 2025.

Forecasts of petroleum and coal use for residential, commercial, industrial, and non-highway transport sectors were based on U.S. Energy Information Administration (EIA) forecasts for Mid-Atlantic fuel demand, along with natural gas projections provided by Energy and Environmental Analysis, Inc. (ref: Energy Demand and Price Forecast, [2009 State Energy Plan](#)).

Forecasts for fuel use for the electricity sector and net imports of electricity were based on output from ICF International's Integrated Planning Model® (IPM), an electricity sector modeling software used to support the development of the 2009 State Energy Plan. Energy demand by sector and fuel type was modeled to 2025. From 2025 to 2050, a constant annual rate of growth or decline was assumed. In addition, emissions projections for 2025 and 2050 are also estimated and presented in Table 2 above. These projections include estimated emission reductions due to RGGI and partial implementation of [New York's 15x15 energy efficiency goal](#).

Forecasts of NYS vehicle miles of travel (VMT) were estimated from historical NYS Department of Transportation VMT data (https://www.nysdot.gov/divisions/policy-and-strategy/darb/dai-unit/ttss/repository/vmt_0.pdf). NYDOT estimates that VMT will continue to grow at a 1.1% per year growth rate out to 2030, and is assumed to grow at this pace to 2050. The annual rate of growth of VMT was 2.5% between 1975 and 1990, and 1.7% between 1990 and 2005 (See [Strategies for a New Age: New York State's Transportation Master Plan for 2030](#).) On-highway diesel and gasoline fuel use was based on NYS VMT along with the Department of Energy's Energy Information Agency-projected vehicle economy, and was the basis the estimate of emissions from the transportation sector.

Finally, non-fuel combustion GHG emission forecasts for the industrial sector were based on the projected growth of New York industries. These forecasts were created using Policy Insight® version 8.0, macroeconomic modeling software from Regional Economic Models Inc. Estimates for emissions from hydrofluorocarbon (HFC) refrigerant substitutes are scaled from EPA projections for national emissions by New York State's relative use of air conditioning, refrigerators, and freezers. Emissions from electricity transmission and distribution were assumed to continue to decline, following the long-term historical trend.

A more detailed explanation of the forecasting methods can be found in the NYS State Energy Plan Energy Demand and Price Forecast Assessment. GHG emission forecasts are in large part based on these energy-use forecasts. A more detailed explanation of the sources and methodologies for GHG emissions can be found in the [New York State Greenhouse Gas Emissions Inventory and Forecast](#) for the [2009 State Energy Plan](#).

Appendix B

GHG Emissions Scenario Assumptions

Sector	Yellow	Deep Blue	Ultraviolet
Transportation	<p>Smart growth reduces VMT Demand 10% for LDV Fleet mix composed of CV/HEV/PHEV* = 30/30/40 CV reaches 37 mpg; HEV miles at 50mpg 95% of VMT for PHEV are all-electric 50% of HDV miles switch to freight transport by rail 30% efficiency gains in aviation</p> <p>~51.3 MMT CO₂e</p>	<p>Smart growth reduces VMT demand 40% for LDV 100% of VMT for LDV from hydrogen (nuclear-based) @65 mpg equivalent 50% HDV VMT switch to freight transport to rail; 40% of balance of miles from biodiesel 30% efficiency gains in aviation, 50% reduction of aviation emissions from biofuel</p> <p>~15 MMT CO₂e</p>	<p>Smart growth reduces VMT demand 40% for LDV 95% of VMT from LDV are all-electric miles Balance of LDV VMT 50 mpg with in-state E85/biodiesel 50% HDV VMT switch to freight transport to rail 30% efficiency in aviation sector; 50% reduction of aviation emissions from biofuel</p> <p>~20 MMT CO₂e</p>
Electricity	<p>25% electricity efficiency in Residential 25% electricity efficiency in Commercial 10% electricity efficiency in Industrial Minimize combustion; what is left switches to IGCC, NGCC w/ CCS Max hydro, wind No new nuclear NO NEW OUT OF STATE RENEWABLE ELECTRICITY</p> <p>~24 MMT CO₂e</p>	<p>Significant efficiency gains as in Yellow Scenario Eliminate all combustion Maximize hydro 30% from carbon-free (nuclear [+2 new plants producing 25K GWh] + hydro) 30% from renewables (utility-scale solar (100,000 GWh), max wind) 40% from NGCC and CCS (@90%) H2 via electrolysis of high-temperature steam using high-T gas-cooled reactors (5-8 plants) NO NEW OUT OF STATE RENEWABLE ELECTRICITY</p> <p>~13 MMT CO₂e</p>	<p>Significant efficiency gains as in Yellow Scenario Maximize hydro, max wind 35% from carbon-free (nuclear [15 new nuclear plants; 24 total], max hydro) 35% from renewables (utility scale solar (100,000 GWh), wind) 17% from NGCC and CCS (@90%) 35%- 40% energy demand in Res./Comm from local solar NO NEW OUT OF STATE RENEWABLE ELECTRICITY</p> <p>~10 MMT CO₂e</p>
Residential	<p>20% efficiency gains in energy demand for heat/hot water 10% of electricity needs met from local solar Reduce combustion by 70-80%</p> <p>~7.5 MMT CO₂e</p>	<p>30% reduction in energy demand through efficiency 50% delivered gas/liquid fuels from biomass 40% of balance of energy demand left met by local solar generation Balance to energy demand from grid</p> <p>ZERO MMT CO₂e</p>	<p>50% reduction in energy demand through efficiency Eliminate all combustion of gas, oil 40% of balance of energy demand met by local solar PV</p> <p>ZERO MMT CO₂e</p>
Commercial	<p>Reduce natural gas/oil combustion by 75% 10% of electricity needs met from local solar Balance of energy need shifted to central electricity</p> <p>~4.5 MMT CO₂e</p>	<p>20%-30% efficiency gains 50% delivered liquids fuels from biomass ~30% of electricity demand from local solar Balance of energy need shifted to central electricity</p> <p>ZERO MMT CO₂e</p>	<p>20%-30% reduction in energy demand through efficiency Eliminate all combustion of gas, oil ~ 50% of energy demand from local solar Balance of energy need shifted to central electricity</p> <p>ZERO MMT CO₂e</p>

Envisioning a Low-Carbon 2050 for New York State

<i>Industrial</i>	<p>Eliminate all coke/coal use Reduce natural gas/oil combustion by 50% Switch coke/coal to natural gas Balance of energy need shifted to electricity</p> <p>~14 MMT CO₂e</p>	<p>20%-40% reduction in energy demand through efficiency Eliminate natural gas, oil combustion Eliminate coke at cement/boilers; switch to natural gas Residual of emissions from asphalt, petrochemical, other (8.4 MMT)</p> <p>~13MMT CO₂e EMISSIONS</p>	<p>20%-40% reduction in energy demand through efficiency Eliminate natural gas, oil combustion Eliminate coke at cement/boilers; switch to natural gas Residual of emissions from asphalt, petrochemical, other (8.4 MMT)</p> <p>~13MMT CO₂e EMISSIONS</p>
<i>Other</i>	<p>Eliminate SF₆ dielectric from T/D grid 50% reduction in line leaks in natural gas RRR policy Eliminate HFC leaks Reduce process CO₂</p> <p>~12 MMT CO₂e</p>	<p>Eliminate SF₆ dielectric from T/D grid Eliminate hydrofluorocarbon emissions Eliminate 90% line leaks in natural gas RRR policy to eliminate 100% municipal methane/waste emissions Eliminate HFC emissions</p> <p>~12 MMT CO₂e EMISSIONS</p>	<p>Eliminate SF₆ dielectric from T/D grid Eliminate hydrofluorocarbon emissions Eliminate 90% line leaks in natural gas RRR Policy to eliminate 100% municipal methane/waste emissions Eliminate HFC emissions</p> <p>~12 MMT CO₂e EMISSIONS</p>

CV = Conventional Vehicle; HEV = Hybrid Electric Vehicle; PHEV = Plug-in Electric Hybrid Vehicle; LDV = Light Duty Vehicle; HDV = Heavy Duty Vehicle; VMT = Vehicle Miles Travelled;
 MMT CO₂e = Million Metric Tons CO₂ Equivalent

Appendix F

2050 Visioning:

Brookhaven National Laboratory Report

As part of its climate action planning, the state of New York is unique in undertaking a visioning process to assist the long-range goal of reducing greenhouse gas emission 80 percent below the levels emitted in 1990 by the year 2050. To develop a plan capable of setting in motion the radical, long-term changes required to achieve the 80 by 50 goal, the Council and its technical work groups and panel — indeed, decision makers at many levels — must be able to imagine the kind of low-carbon clean energy future toward which they are working.

An initial step in that visioning process was a conference held January 5, 2009, *Envisioning a Low-Carbon Clean Energy Economy in New York*. The conference, organized by the New York Academy of Sciences, Brookhaven National Laboratory, the New York State Energy Research and Development Authority, and the New York State Department of Environmental Conservation, involved members of the Climate Action Council, the Integration Advisory Panel, and the Technical Work Groups.

Led by subject matter experts, the participants in the workshop explored innovative strategies for meeting the State’s energy needs, reducing energy demand, managing greenhouse gas (GHG) emissions, driving technological change, and creating economic opportunities for “green-tech” in New York. The workshop considered specific scenarios that outlined possible pathways to reducing GHG emissions. The purpose was not to validate a particular pathway, but rather to explore possibilities and their implications, as well as to identify obstacles to achieving the goal.

The January conference led to the creation of the report, *Envisioning a Low-Carbon Clean Energy Economy in New York*, produced by Brookhaven National Laboratory and appended here in its entirety and keeping its original pagination.

Envisioning a Low-Carbon 2050 for New York State

**A white paper submitted to the
New York State Climate Action Council**

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October 1, 2010

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Important note to readers:

This is the first complete draft of a paper designed to inform the NYS Climate Action Council's work to develop a State Climate Action Plan.

The Council's mandate is uncommonly broad in scope. It has a planning horizon far longer than what most planners address. It entails large uncertainties. No clear precedent for an enterprise of this scope exists.

Consequently, this draft paper is necessarily provisional. As the planning process proceeds, the paper will be revised, and it will steadily gain in value as fresh insights are acquired and the knowledge base it draws from expands.

One feature of this paper is a description of three scenarios that illustrate different versions of a low-carbon 2050 future for the state. It's important that readers understand that these scenarios are offered for illustrative purposes only. In no sense do they constitute the elements of a plan, and indeed even a casual review of them reveals that there is no way in which they could be fashioned into a plan. Rather, they're intended to facilitate and provoke thinking about the future.

We hope other parties will generate their own 80x50 scenarios and share them. The ability to *imagine* a sustainable future, model it rigorously, and explore it is as vital to achieving that future as the clean-energy technologies, best management practices, and behavioral changes that must be developed, advanced, and adopted.

SUMMARY

The State of New York aims to reduce state greenhouse gas (GHG) emissions to 80% below 1990 levels by 2050. The fact that the state is already more energy efficient than most other states makes this goal particularly ambitious. A State Climate Action Council is charged with developing a draft Climate Action Plan by November, 2010. Toward this end, it has organized technical work groups and an integration advisory panel of stakeholders and experts.

To develop a plan capable of setting in motion the radical, long-term changes required to achieve the 80x50 goal, the Council and its team must be able to imagine the kind of low-carbon future toward which they are working. To facilitate this, the Council also formed a [2050 Visioning Advisory Panel](#). Comprising experts from many fields, that panel was convened at a workshop held on January 5, 2010.

This draft visioning paper draws from insights and knowledge shared at that workshop, and from other expert sources. It also draws from three GHG mitigation scenarios for 2050 that we developed for the workshop to illuminate how a low-carbon future might be achieved, and what it would mean. Making assumptions about future energy demand, patterns of energy use, the technologies that might be available to supply needed energy with reduced emissions, and what their levels of performance might be, we estimated emissions for each major sector of the state's economy. We found that reaching the 80x50 goal is challenging and that modeling required aggressive assumptions.

Together, the workshop, scenario development, and the crafting of this visioning paper constitute a "visioning process." Its focus has been manifold: an examination of technologies that might prove scalable and those that might be dead ends, of technical issues that require assessment, of policies that favor or constrain GHG reductions, and of management and societal changes needed to reduce emissions.

While the state's energy future cannot be predicted, some points are already clear, among them, these:

- Reducing emissions is imperative because atmospheric levels of GHGs are already perilously high, and emissions are cumulative – and there are real costs associated with inaction.
- The 80x50 goal is ambitious, and achieving it will require investments in new energy systems and infrastructure that have very low or no net carbon emissions. Patterns of energy use will also need to change.
- Energy efficiency is an essential, but not sufficient, strategy that can be aggressively pursued today.

- A broad shift from reliance on burning fossil fuels to electricity generated from low- or no-carbon sources, or widespread use of carbon capture and sequestration, will be needed.
- Transportation and buildings (residential and commercial) will have to move away from reliance on combustion of fossil fuels to alternate sources with significantly lower carbon or no carbon emissions.
- Development and redevelopment based on smart growth principles, as well as the building design practices, building technologies, and construction methods can significantly reduce the energy demand for buildings, as well as transportation.
- Incremental, short-term planning cannot achieve the goal. Near-term decisions – both those taken and not taken – can preclude longer-term options, such as infrastructure projects requiring long lead times. Key climate strategies *must* reflect this inexorable reality.
- The goal must be pursued in part through extensive, long-term partnering among all levels of government and across the region, and between the public and private sectors. It will take sustained effort on the part of all.

THE BROAD CONTEXT FOR THIS PAPER

In the face of climate change, the stakes are so high, the challenge so immense, and the opportunities so richly promising that business as usual and conventional wisdom are themselves risky. Innovation is imperative — not only in technology but in ways of thinking, working, and living.

In fact, what's demanded transcends "innovation": transforming an entire economy from largely carbon-based energy sources to largely carbon-neutral sources in a scant 40 years will be a true revolution, a radical shift that can renew New York's economy, enhance its natural environment, and improve its citizens' quality of life for generations to come.

For this revolution to succeed, institutions must be mobilized, businesses must adapt or fail, and individuals, families, and communities must make better-informed energy choices. And all of this change must be scaled up massively and rapidly.

The 80x50 challenge

Recognizing the benefits of action and the risks of inaction, in August 2009 the Governor signed [Executive Order 24](#), which tasks the State to reduce GHG emissions from all sources within the state to a level 80% below the 1990 level by 2050. It establishes a Climate Action Council that is to develop a Climate Action Plan to achieve that goal, taking into account economic and other considerations. The plan is to be drafted by November, 2010. The Council will hold public comment hearings on the draft and after reviewing comments prepare a final plan.

That plan will be reviewed annually and revised as appropriate. The Executive Order says it "is not intended to be static, but rather a dynamic and continually evolving strategy to assess and achieve the goal of sustained reductions of greenhouse gas emissions."

To advance and inform its work, the Council has convened stakeholders from New York, as well as experts from New York and beyond, and organized them into technical work groups and an integration advisory panel. Working in support of the Council and these groups is the [Center for Climate Strategies](#). The Council's comprehensive [web site](#) offers detailed information about its work, and it links to the *New York Greenhouse Gas Emissions Inventory and Forecast*. Readers unfamiliar with the Council are urged to consult the site for essential information that complements this paper.

How visioning contributes to the Council's work

To develop a plan capable of setting in motion the radical, long-term changes required to achieve the 80x50 goal, the Council and its technical work groups and panel must be able to imagine the kind of low-carbon clean energy future toward which they are working. To

facilitate this, a [2050 Visioning Advisory Panel](#) comprising experts drawn from many fields was convened at a January 5, 2010, workshop held at the New York Academy of Sciences. At the workshop, the experts made presentations and responded to concerns and questions from the floor. (The link above leads to a link to a webinar of the workshop, the slides speakers showed, and the agenda.)

This draft paper draws from insights and information shared at the January workshop. It also draws from many other expert sources, such as reports from the National Academies of Science. And it draws from three GHG mitigation scenarios for 2050 that we developed for the workshop, described below. Together, the workshop, the development of scenarios, and the crafting of this visioning paper constitute what may be termed a “visioning process.”

The focus of the process has been manifold: an examination of technologies that might prove scalable and of those that might be dead ends, of technical issues that must be addressed, of policies that favor or constrain GHG reductions, and of management and societal changes needed to reduce emissions. Of course, policies that favor GHG reductions must be implementable. But for a time horizon so far distant, at this early stage, technical feasibility and cost considerations can be considered only in broad-brush terms. This paper treats them accordingly.

Our scenarios suggest that, in concept, the 80x50 goal is technically possible. The overall visioning process makes clear that incremental, short-term planning alone cannot meet the goal and that even a sophisticated long-term approach must surmount serious challenges. This in turn underscores how important it is that climate change vulnerability analyses and adaptation planning proceed on equal footing with mitigation efforts.

But the scenarios reveal a world of opportunities, too, that hold tremendous potential for the state’s economy and its citizens’ well being.

THE APPROACH TO ENVISIONING A LOW-CARBON 2050

The technical work groups that are contributing to development of the State's Climate Action Plan process are responsible for recommending specific strategies, policies, and actions for the Council's consideration. The visioning process, defined above, was designed to complement their work. Scenarios are a uniquely valuable tool for this purpose. Scenarios have been widely and routinely used, for many years, in many fields, as a tool for exploring options and contingencies. The three scenarios we developed for the State's January visioning workshop investigated the technical feasibility of the 80x50 goal and identified some technology options and best practices that could achieve the goal. The scenarios also helped us identify some significant technical barriers and policy issues that might facilitate or constrain those options.

To model and gain insight into possible futures, we "worked backward" from an imagined mid-century New York that has far lower GHG emissions. Making assumptions about future energy demand, patterns of energy use, what technologies might be available to supply energy and reduce emissions and what their levels of performance might be, we estimated emissions for each major sector of the economy, considering many interchangeable elements that might be dictated by policy implementation, technology breakthroughs, or market developments in the US and abroad.

The value of the scenarios is in providing a framework for thinking concretely about how energy efficiency, new energy technologies, fuel switching, best practices, and other matters might shape the path to a low-carbon future. Scenario modeling can also provide insight into performance levels for new energy technologies such as plug-in hybrid electric vehicles (PHEVs), or emission-reduction technologies such as carbon capture and storage (CCS).

All three of the 80x50 scenarios share important characteristics:

- An end state is postulated for each major energy-consuming sector of the economy: Transportation, Electricity Production and Distribution, Residential Buildings, Commercial Buildings, and Industrial. These end states are largely characterized by their technological characteristics, such as low carbon-emitting central generation of electricity, electric vehicles, and net-zero carbon emission buildings.
- Next, the ramifications of these technology options are examined. For example, if the state were to depend on hydrogen as a transportation fuel, how would the hydrogen be produced? Similarly, if the goal is low-carbon electricity central generation, what are the technology options for generating that power?
- Finally, the resulting scenario is referenced to a projection of what the energy use may be in absence of carbon abatement policies; that is, in the "business as usual case" (BAU). This comparison illuminates, for example, the magnitude of energy-efficiency gains that might be required, or the extent to which projected

transportation needs that light duty vehicles would otherwise meet could be met by expanded mass transit instead.

THREE SCENARIOS FOR 2050

Models, assumptions, and limitations

The three scenarios were designed to answer these basic questions:

- What are possible, illustrative scenarios in which NYS GHG emissions would be ~80% lower than the 1990 level of ~251.4 million metric tons (MMt) of CO₂ equivalent (CO₂e)? (a goal of about 51 MMt)
- What are the implications of such scenarios?

To support the modeling exercise, a macro model of statewide GHG emissions was developed. Data are presented in Table 1, below. Emissions data for 2007 are the most recent available and are considered “current” for the purpose of this paper. NYSERDA projects that 2025 annual GHG emissions will be 266 MMT CO₂e, a relatively small increase from current levels. The relative contributions of the various sectors remain unchanged, except that the “Other Source” category (non-fuel combustion) is projected to surpass residential emissions by 2025. (“BAU” is the “business as usual projection.”)

Table 1. Sector GHG Emissions for Select Years (in Million Metric Tons CO₂e)

	1990	2007	2025	2050
	(actual)	(actual)	(forecast)	(BAU Projection)
Transportation	72.9	88.4	93.4	114.3
Electric	64.5	49.2	42.9	75.5
Electric Imports	1.7	7.4	7.6	-
Residential	34.1	37.6	34.7	40.8
Commercial	26.8	27.3	30.1	35.4
Industrial	25.0	19.2	18.7	21.9
Other	26.5	28.7	38.5	39.0
TOTAL	251.4	257.7	266.0	326.6

Scenario modeling was a rigorous process that began by estimating the total energy demand that might have to be met in 2050 in each sector. This was done by extrapolating current forecasts and assuming modest growth in state GDP and hence energy demand.

These assumptions create the future “business as usual” (BAU) emissions scenario – the case that perpetuates the path we are on. BAU energy demand projection estimates the energy supply needed to support the state’s economy in 2050 given our current patterns of transportation, energy use and efficiency.

The foundation of our scenario development is a state-level, coupled-sector macro model of energy supply flows and corresponding (calculated) emissions for each sector of the economy. In addition, possible reductions in non-energy related emissions (the “Other”, non-energy related category) were estimated.

Table 2. Estimated Energy Demand by Sector

	2007	2025	2050
	(actual)	(forecast)	(BAU Projection)
Transportation			
LDV/HDV VMT	136B Miles	170B Miles	224B Miles
Aviation	210 Mbtu	222 Mbtu	240 Mbtu
Electric	165,000 GWh	187,000 GWh	270,000 GWh
Residential	591Tbtu	629Tbtu	721Tbtu
Commercial	533Tbtu	557Tbtu	587Tbtu
Industrial	191 Tbtu	180 Tbtu	180Tbtu

In the table above “LDV” means “light duty vehicle; “HDV” means “heavy duty vehicle; “VMT” means “vehicle miles traveled.”

We then took the energy demand forecast for each sector, presented in Table 2, above, and traced energy flows through each sector as primary energy (e.g., coal, biomass) and energy carriers (e.g., gasoline, #2 and #6 oil, coal, etc.) would be used for such purposes as creating electricity, heating homes, providing power for businesses and manufacturing sectors, and fueling light duty and heavy duty vehicles. For each of those uses, we calculated corresponding emissions. Fuel energy content and emissions factors for combustion come from [US EPA data tables](#).

Significantly, unlike conventional “wedge” models, which treat sectors as freestanding, the coupled-sector model we employed reflects the fact that switching technologies in one sector may raise or lower demand in another. For example, two scenarios (the “Yellow” and “Ultraviolet”) depend on widespread use of PHEVs in the transportation sector, resulting in a

decrease in gasoline demand and an increase electricity demand; thus, primary energy demand switches to the electricity sector.

A note of caution: The scenario modeling provides insights into how technologies and patterns of energy use may have to change to meet emissions targets. But there are limitations to using the scenarios. This sort of modeling is not a practical planning tool, as it does not account for the crucial factor of scalability, or for economic, regulatory, and other barriers to the implementation of any given technology, including the availability of the raw material required. Nor does it take into account lifecycle analyses of nuclear power and renewable energy technologies. The models also do not consider the future interaction between a changing climate and energy use and impacts on the performance of different technologies.

The models do include estimates of the performance of new and emerging energy technologies for which the predicted development time scales are commensurate with the State's 40-year planning timeframe. Assumptions about the performance of new, emerging energy technologies are based on credible estimates from available literature, though there can be no guarantee that as-built systems will meet the estimated levels of performance, be economically viable, or penetrate the market at rates needed to meet assumed levels.

A note on methodology and references: For more information on methodology and data sources used in our modeling, please see Appendix A. For more detail on the scenarios, see Appendix B.

Basic strategies for reducing emissions

Developing scenarios that illustrate potential approaches to meeting the 80x50 emissions target of ~50 MMT CO₂e requires recognition of the fact that those emissions result from activities that power our society and our economy, providing food, shelter, heating and cooling, communications, transportation, and innumerable other things essential to well-being. Cutting GHG emissions could have real-world consequences if low-carbon or no-carbon energy sources don't adequately replace fossil sources.

The scenarios rely on four key strategies to reduce GHG emissions:

- The simplest and the most cost-effective is energy conservation through energy efficiency.
- Reducing combustion from fossil fuels is another obvious strategy, as that combustion accounts for about 87% of all GHG emissions in New York State, with the largest fraction coming from the transportation sector (38%), followed by on-site combustion in the residential, commercial, and industrial sectors (37%), and then from electricity generation (22%). All scenarios assume that combustion of fossil fuels should only be used when and where necessary, or where controls such as CCS

effectively limit emissions. Minimizing point sources of combustion such as vehicles and use of oil and natural gas for heating, and switching to electricity, coupled with simultaneously reducing the GHG footprint of the electricity supply, thus constitutes the second strategy.

- The third strategy is to drive fuel switching where combustion must still be used, as in aviation and cement production, to minimize the GHG footprint.
- Using local, point-of-use renewable energy technologies such as solar to reduce the reliance of homes and businesses on centrally generated electricity is the fourth strategy.

By varying these strategies and devising portfolios of energy technologies and practices that could implement them, we created three scenarios that we named “Yellow,” “Deep Blue,” and “Ultraviolet.” The Yellow scenario falls far short of the 80x50 goal; the other two scenarios meet it, in different ways.

The Yellow scenario

The Yellow scenario does not meet the ~50 MMT CO₂e GHG emissions challenge. It is intended to be a “first cut” at reducing GHG emissions through increased efficiency: the adoption of more efficient energy technologies that are largely available today, or will be soon. This scenario assumes a significantly different mix of light-duty vehicles (LDV) in use in 2050, with 30% being conventional internal combustion engines with an average of 37 mpg, 30% being hybrid electric vehicles (HEV) with an average of 50 mpg, and 40% being plug-in hybrid electric vehicles (PHEV) with 95% all-electric miles. This produces a modest increase in demand in the electricity sector of about 20,000 GWh. The use of intermodal freight shipping is assumed to reduce vehicle miles traveled (VMT) for HDV by about 30%.

In the electricity sector, it’s assumed that New York State wind and hydro-electric generation will be built out to meet the maximum forecasts developed by NYSERDA, and that there will be a very significant increase (up to 100,000 GWh) of utility-scale solar electric generation or other renewable source such as off-shore wind. Where combustion is used for electricity, a switch to higher-efficiency natural gas combustion turbine (NGCT) and integrated gasification combined cycle (IGCC) power plants with CCS at 90% is assumed. It’s also assumed that present levels of nuclear power generation can be maintained. Transmission and distribution losses are reduced by 50% to an average of 4% for the entire system. Residential, commercial, and industrial sectors reduce electricity demand via Energy Star+ efficiency gains.

This scenario includes elimination of 75% of all fossil fuel combustion in the residential and commercial sector, with natural gas and liquid fuels replaced by electricity, some generated on-site via solar (about 10% of the energy demand), and the balance generated at utility

plants. Industrial emissions are reduced by curtailing fossil fuel combustion overall by 75% and using only natural gas and #2 oil; coal is eliminated in favor of natural gas.

Reductions in non-energy emissions (the “Other” category) assume elimination of sulfur hexafluoride (SF₆) dielectric from the transmission and distribution grid. Per molecule, SF₆ has the highest GHG warming potential, about 23,900 times that of CO₂. Reducing natural gas line leaks (by 50%), implementing a broad and aggressive *reduce, reuse, and recycle* policy, and eliminating leaks of alternative refrigerants (hydrofluorocarbons [HFCs]) would reduce emissions from these sources significantly.

The Yellow scenario results in about 114 MMT CO₂e emissions, a reduction of 55 percent below the 1990 level. It thus falls far short of the 80x50 goal – a sobering fact, given how much it differs from today’s energy patterns.

The Deep Blue scenario

The Deep Blue scenario meets the ~50 MMT CO₂e GHG emissions challenge. It begins with the efficiency savings outlined in the Yellow Scenario and then explores alternatives if fossil fuel combustion in the residential and commercial sectors were to be eliminated, thereby driving an increase in electricity demand. Some of the increased electricity demand is assumed to be met with a larger fraction of point-of-use solar.

The Deep Blue scenario explores the impact of widespread adoption of hydrogen-powered light-duty vehicles for 100% of the LDV VMT with an equivalent of 65 mpg. The scenario assumes that hydrogen is produced through high-temperature steam electrolysis using gas-cooled high-temperature nuclear reactors. Because this approach employs a carbon-free electricity source, emissions are minimized. The calculations suggest the need for ~5 to 7 GW of nuclear capability for electrolysis. Gas-cooled reactors are well known conceptually, but significant technological and regulatory developments are needed. An alternative source of electricity could involve the use of IGCC or natural gas combined cycle (NGCC) with CCS. High-temperature steam electrolysis is an unproven technology at this time. The scenario does not address infrastructure issues associated with the transformation to a hydrogen-based transportation system.

The scenario assumes that 100% of all fossil fuel combustion in the residential and commercial sectors is eliminated and that the use of natural gas and liquid fuels is replaced by electricity, some generated onsite via solar (about 40% of the energy demand), the balance generated at utility plants. Industrial emissions are reduced by curtailing fossil fuel combustion overall by 75% and using only natural gas and #2 oil; coal is eliminated in favor of natural gas. Importantly, 8.4 MMT of the 13 MMT in emissions in the industrial sector are residual emissions from asphalt, petrochemical production, etc. It will be important to devise methods for curbing emissions from asphalt production to make further reductions.

Electricity demand is met from carbon-free sources, including 30% from nuclear (including 2 new plants that would increase nuclear power generation by 25,000 GWh, not counting the additional reactors required for hydrogen generation), 30% from renewables (maximum hydro, wind, and 100,000 GWh of solar), and 40% from NGCC plants with 90% CCS. It is important to note that the emission levels from NGCC limit generation from this source unless CCS is achievable at levels higher than 90%. This would make the future use of natural gas or coal for the electricity sector dependent upon the viability of CCS for locations and geologies within the state, and upon the amount of CO₂ that can ultimately be stored.

In addition, the Deep Blue scenario assumes that emissions in aviation and the residential, commercial, and industrial sectors could be significantly reduced through the use of in-state, bio-derived oils for transportation (diesel), aviation (jet fuel), and heating. Given the potential for reduced emissions in the aviation, residential, and commercial sectors – as well as for HDV transportation – these replacement fuels warrant serious consideration, as do studies of the feasibility of supplying bio-derived oils for fuel from within the state. At present, net carbon emissions from these sources are assumed to be zero or close to zero, as carbon emitted by combustion of the biofuel is offset by carbon sequestered by plants grown to supply fuel. (See EPA's [2009 U.S. Greenhouse Gas Emissions Inventory Report](#).) Further study regarding the total carbon cycle associated with the use of these fuels is warranted to validate the emissions assumptions.

The Deep Blue scenario estimates emissions at 53 MMT. It thus achieves a 79 percent reduction in GHG emissions below the 1990 level.

The Ultraviolet scenario

Another possible future was devised that would also meet an 80 percent reduction by 2050. Like Deep Blue, the Ultraviolet scenario is much more aggressive than the Yellow scenario. It too begins with the efficiency savings outlined in the Yellow scenario and explores alternatives if fossil fuel combustion in the residential and commercial sectors were eliminated, thereby driving an increase in electricity demand. A part of this electricity demand is met through local, point-of-use solar.

The Ultraviolet scenario explores the impact of shifting to widespread use of PHEVs where 95% of VMT are all-electric miles, with 5% of VMT coming from bio-ethanol at 50 mpg. This is an aggressive goal, well beyond current predictions for most studies of PHEV market penetration and performance improvements through 2030. Significant increases in electricity demand are postulated via elimination of fossil fuel combustion in the transportation sector for LDV.

The scenario assumes that 100% of all fossil fuel combustion in the residential and commercial sector is eliminated and that the use of natural gas and liquid fuels is replaced by electricity, some generated onsite via solar (about 40% of the energy demand), the balance being generated at utility plants. Industrial emissions are reduced by curtailing

fossil fuel combustion overall by 75% and only using natural gas and #2 oil; coal is eliminated in favor of natural gas. As in the Deep Blue scenario, 8.4 MMT of the 13 MMT in emissions in the industrial sector are residual emissions from asphalt, petrochemical production, etc.

The significant increase in electricity demand is met largely with carbon-free sources: 35% from nuclear (including ~10-12 new plants), 35% from renewables (maximum hydroelectric, maximum on-shore wind, and 100,000 GWh of solar or other utility scale renewable such as offshore wind), and 17% from NGCC plants with 90% CCS. This scenario employs as much NGCC with CCS as is practical to meet overall emissions targets, thereby requiring a larger fraction (and level) of carbon-free sources. They are assumed to be met with new nuclear plants.

As with the Deep Blue scenario, this scenario relies on the use of low carbon-intensity bio-derived fuels (in-state ethanol) to supply the liquid fuel needed for non-electric miles in the LDV category, and on the use of biofuels in the aviation sector.

The Ultraviolet scenario estimates emission at 55MMT, a 78 percent reduction in GHG emissions below the 1990 level.

SERIOUS CHALLENGES POSED BY THE LOW-CARBON GOAL

The scenarios, presentations, and discussion at the January 5 workshop illuminated issues and challenges facing the Council. In particular three sectors – transportation, electricity generation, and buildings – emerged as particularly challenging and significant. At present, the transportation sector produces 34.3% of the state’s GHG inventory; electricity generation, 19.1%; residential uses, 14.6%; commercial uses, 10.6%. The “business as usual” (BAU) case for 2050 projects that the transportation sector will produce 35%; electricity generation, 23.1%; residential, 12.5%; commercial, 10.8%; and industrial, 6.7%.

The text below discusses the challenges those sectors present.

Serious Challenge: Transportation

Mobility is essential to social and economic welfare. By all measures, New York is one of the most mobile states in the nation. It has over 11 million licensed drivers, 10.5 million motor vehicles – virtually all of them operating on fossil fuel, and joined by similar vehicles that travel to New York from other states – and 113,000 miles of roads, along with 4,800 miles of railroads, 18 commercial airports, and 495 public use and private airports. Ensuring a safe, secure, reliable, efficient, low-carbon transportation system is vital to the state’s future. (See [Strategies for a New Age: New York State’s Master Transportation Plan for 2030.](#))

Today’s transportation systems are defined by technological, socioeconomic, land use, and public policy factors. Transportation demand is growing, and patterns of travel are changing and increasingly reliant on multiple, interdependent modes of transportation. Congestion in urban areas is growing, and transportation systems in these areas are bounded by the built environment. Over the next 40 years, the transportation system will have to support the same or greater levels of mobility while lowering emissions dramatically. And the importance of transportation security to national and economic security is expected to increase.

Over the past three decades, tremendous growth in the transportation sector and the decline in US oil production have made the US and New York increasingly dependent on foreign supplies of petroleum. Today, about 60% of the oil consumed in the US is imported. In New York, transportation accounts for about half of petroleum consumption, the equivalent of about 300 million barrels per year, or about 4% of the US total. As the potential for disruptions in world oil supply and production of refined petroleum products increases, so does the risk of disruption to the state’s transportation system. Given projected growth in demand for oil in emerging markets, notably China and India, the cost of oil and the reliability of supply are important risk factors to consider.

Within the transportation sector, road transport is the largest consumer of energy and the largest source of emissions. The major contributors to emissions are light duty vehicles (LDV), a category that includes automobiles, SUVs, motorcycles, and light trucks, and heavy duty vehicles (HDV), which includes trucks for road freight as well as buses. After road transportation, aviation is the next biggest contributor. Another important factor is the impact of the design and construction of the local built environment on mobility and patterns of use of available modes of transportation.

Addressing transportation requires a holistic look at all the factors that can improve efficiency as well as reduce emissions. In general, approaches to transportation examine (1) society's future mobility needs, (2) the technical efficiency of a given mode of transportation and the potential for improvements, (3) the effects of the operating environment, and (4) the mix of transportation modalities and potential systems performance improvements via changes in the mix of modalities.

Transportation and the built environment

The New York metropolitan area enjoys an extensive public transportation system that is well integrated into the region. Some 4.8 million passengers use public transportation on a daily basis. The high density of housing, proximity to public transportation, and its relative ease of use contribute to this high level. Aspects of the region have attributes of "compact, mixed-use development" – also known as "smart growth."

In all of the mitigation scenarios, a significant reduction in projected VMT level for 2050 (240 billion miles) is assumed. The assumption is that smart growth can promote greater reliance on public transportation and/or increase walking and bicycle travel. At the January 5 visioning workshop, success stories about smart growth in urban and suburban areas were recounted – notably for Arlington, Virginia, and Portland, Oregon. They offer models for New York's suburbs and for cities other than New York City; for example, the corridors in Long Island along the Long Island Railroad and major traffic arteries.

Over the 40-year horizon of the Climate Action Plan, many urban and suburban centers will very likely be rebuilt or redeveloped. This will create opportunities to reshape the state's transportation system and its use – if transportation planning and redevelopment efforts are approached holistically and use smart-growth practices. As redevelopment in urban and suburban areas occurs, more compact, mixed-use development that includes higher population and employment densities, competitive alternatives to automobile use such as pedestrian and bicycle paths, street networks that provide connectivity between destinations, and easy access to public transportation can all reduce residential and commercial energy use, GHG emissions, and VMT.

A recent and comprehensive [study](#) by the Transportation Research Board of the National Academies explores the impact of and correlation between driving behavior and the built environment. It concludes that compact, mixed-use development can reduce VMT by

differing means and amounts depending on where the development in a region occurs. The study reports that the literature suggests “that doubling residential density across a metropolitan area might reduce VMT by about 5-12%, and perhaps as much as 25% if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures.” It also notes that more study is needed to better understand the causal links between specific design elements in land use, transportation pathways, high density housing, employment centers, and other factors and reductions in VMT and increased use of public transportation.

To significantly reduce VMT would require changes in current practices and patterns of development in suburban areas. In home-rule states like New York, land use is largely a function of local governments, which can be reluctant to zone for higher-density housing because local residents often resist it. Statewide change would require that state-level policies be enhanced with incentives that encourage and support compact, mixed-use developments that would result in greater energy efficiency, increased use of public transportation, and reduced VMT and GHG emissions.

These efforts would be facilitated by communitywide design standards (the equivalent of LEED certification); the development of partnerships among State and local governments and private developers; tax incentives; coordinated State, federal, and local infrastructure investments; coordination with regional transportation authorities and operators; and rezoning to support appropriate transit development.

Light duty vehicles

In 2007 New York State residents drove over 140-billion VMT and consumed some 7.6 billion gallons of gasoline [EIA, Energy Consumption 2007], largely through the use of personal vehicles. As our mitigation scenarios reveal, significant emission reductions are possible in the transportation sector. The scenarios explore three alternative future vehicle fleets: one a mix of conventional, hybrid, and plug-in hybrid electric vehicles (PHEVs) (Yellow scenario); one dominated by hydrogen vehicles (Deep Blue); and one dominated by PHEVs (Ultraviolet). The latter two scenarios show that fuel switching will drive increased demand for electricity production, either for vehicle re-charging or electrolysis of steam for hydrogen production. Of course, emissions reductions would only be realized by the use of nearly carbon-free electricity sources such as renewables, nuclear, or natural gas or coal-fired plants with CCS.

What will it take for the US to realize 100% PHEV or 100% all-hydrogen powered cars on the road in 2050? Significant changes to automobile technology, of course. However, replacing New York’s entire fleet of automobiles will take time. The lifetime of a car is long; the mean lifetime is about 15 years: half the cars sold today will still be on the road in 15 years, and it will take about 25 years for 95% of the autos sold today to be retired. (See the ORNL [Transportation Energy Data Book](#) [2009 ORNL-6984]). Thus, to achieve a fleet

composed of 100% PHEV cars in 2050, 100% of the cars sold in 2025 and every year thereafter would have to be PHEVs. The same case applies to hydrogen-fueled cars.

Another reason why changing the entire fleet will take time is that it takes time for transportation equipment and automobile manufacturers to adopt new technology and integrate it into their product lines and manufacturing processes. At present, automobile models undergo a complete redesign approximately once every 8 years, and new designs are locked in about 2 years in advance. Thus, it could take from 5-10 years for a new automobile design to be brought to market, and another 25 years to completely change over the fleet.

For PHEVs, this penetration rate is more aggressive than what experts are predicting. For example, a recent study by the National Academy of Sciences (NAS), [Transitions to Alternative Transportation Technologies – Plug-in Hybrid Electric Vehicles](#), concluded that PHEVs are “unlikely to achieve cost effectiveness before 2040 at gasoline prices below \$4.00 per gallon,” given the higher costs when compared to conventional vehicles. Further, the NAS PHEV study concluded that “at a maximum practical rate, as many as 40 million PHEVs could be on the road by 2030, but various factors (e.g., high cost of batteries, modest gasoline savings, limited availability of places to plug in, competition from other vehicles, etc.) are likely to keep the number low.”

PHEVs are scheduled to enter the US market in the 2011-2013 timeframe. They will have an all-electric range of ~30-60 miles. For mass-market penetration, a greater all-electric range of around 100 miles or more would be needed – underscoring the need to develop higher performance battery technologies. Costs must come down, too. Drivers include electronic controls, drive trains, and batteries. Lithium-ion battery technology has been developing rapidly, though costs are still high and, according to the NAS study, expected to decline only by about 35% by 2020. Further technology development will likely reduce costs below these levels, as well as increase storage density and reliability, possibly by using alternative chemistries to lithium ion batteries.

Other notable barriers include the need for suitable charging stations or battery exchange facilities and consumer acceptance of PHEVs, especially if PHEVs cost more than similar functioning hybrid electric vehicles and require daily (or more frequent) recharging. Adoption of PHEVs by large vehicle fleets, such as federal, state, and local government fleets, may be an appropriate first step to increase adoption, if costs are reasonable.

The Deep Blue scenario explores the potential impact of fuel switching from gasoline to hydrogen for vehicles. Hydrogen vehicle technologies largely follow two paths: direct burning of hydrogen in a suitably modified internal combustion (IC) engine or use of electrochemical fuel cells (proton-membrane exchange fuel cell [PMEFC]) which, in turn, drives an electric motor. Hybrids of electric and combustion processes are also conceivable – PMEFC with batteries, for example. It is important to note that hydrogen-based ICs and PMEFCs have applications in local point-of-use generation of electricity. It’s conceivable that ICs and PMEFCs could be used for hot water, lighting, and heating in residential and

commercial applications, as well. Studies of the energy efficiency of hydrogen (such as the National Academies of Science's [The Hydrogen Economy](#)) find that the hydrogen vehicles would not substantially reduce total energy use per mile driven (the "wheels to wheels" energy per mile driven) unless the hydrogen were produced from wind or solar power.

The Deep Blue scenario relies on nuclear power with high temperature electrolysis of water to produce hydrogen, with electricity and heat generated from a nuclear reactor. Alternate approaches include steam reforming of methane using process heat provided by a very-high temperature nuclear reactor, or through a thermochemical cycles, such as the sulfur iodine process. Steam reforming of methane is widely used in industry to make hydrogen today, and this [process](#) is well established. Carbon release from steam reforming of methane would compromise emissions gains through the use of nuclear power and is a potential showstopper, though carbon capture is not inconceivable.

Beyond nuclear-based approaches that rely on steam reforming, several technologies are envisioned for large-scale or central generation of hydrogen. Coal and natural gas integrated gasification combined cycle (IGCC) or natural gas combined cycle (NGCC) plants could also serve as a heat source for steam reforming of methane – and for much smaller hydrogen generation scales, solar PV or wind could be used for electrolysis. Of these sources, only nuclear and renewable-based hydrogen production have a zero-carbon footprint, and with the advent of carbon capture and storage (CCS) technologies, central-station hydrogen production from coal or natural gas plants would have a carbon footprint five to ten times smaller than that of gasoline. The price of hydrogen is highly dependent on the way hydrogen would be produced and associated emissions from the generating source. Thus, today, nuclear-based, as well as NGCC or IGCC with CCS, appear to be cost-competitive with gasoline, while the higher cost of electricity generated by renewable sources is two to five times more expensive.

At best, hydrogen represents a long-term option. Significant technological and infrastructure breakthroughs are needed before it's considered viable. Significant improvement in the energy density of hydrogen storage, reductions in fuel cell costs, increased lifetime and reliability, as well as cost reductions in hydrogen production are needed. Safety is also an important factor. Initially, transportation and distribution of hydrogen would entail transport by truck to regional distribution centers, using compressed gas cylinders. Over time, the use of hydrogen to fuel vehicles would require construction of infrastructure such as pipelines and fueling stations.

To overcome some of the barriers to adoption of hydrogen fuel for PHEVs, New York State would have to work with other states and the federal government to develop requirements that drive the market toward new vehicle technologies. In the meantime, fuel efficiencies and carbon reductions will be realized through improvements to conventional vehicle technologies and greater market penetration of hybrid electric vehicles.

Heavy duty vehicles

Trucks carry the bulk of freight transport. In New York State, 90 percent of commodities by weight are moved by truck, while only 3 percent are moved by rail - a more efficient and less GHG-intensive mode. Freight traffic is expected to grow significantly, with a concomitant growth in VMT. More-efficient, less GHG-intensive modes of transport are clearly needed. In general, there are two ways to reduce HDV emissions: directly reducing truck emissions, and shifting freight from trucks to more efficient and less GHG-intensive modes.

The factors that affect truck emissions and efficiency include (1) the nature of the fleet mix (the size of the trucks), (2) the fuel-efficiency of the trucks, (3) the operating environment (built environment, road conditions, traffic and congestion, etc.), (4) how trucks are operated (speed and idling), (5) the nature of the cargo and truck loading (weight, density, containerized vs. open-bed freight, etc.).

The mix of trucks and their patterns of use are extremely heterogeneous. Efforts to reduce emissions should focus on the largest fuel consumers: tractor-trailers and straight trucks. Tractor-trailer efficiency improvements should start with retrofits to reduce truck frame drag. Estimates indicate that truck retrofit packages (such as aero-cab, front flaring, side skirts, rear tail flaring, low rolling-resistance tires) can improve truck efficiency on the order of 5-10%. Retrofit packages can be readily adopted for existing fleets. (The Union of Concerned Scientists offers information on [green trucks](#). Scroll down that web page for a link to a study by the technology firm TIAX, [Heavy-Duty Truck Retrofit Technology: Assessment and Regulatory Approach](#).)

In addition, future truck fleets will rely on advanced truck engine designs, such as hybrid-electric engines, with an estimated efficiency increase of 7-9%. Adoption of new engine technologies will take time, as the market is conservative and fleet turnover is much slower than for LDVs: the median lifetime of a HDV is well over 20 years. This implies that the penetration of a new technology will take significantly longer in the HDV market than in the LDV market. Consideration should be given to policies that may speed adoption of new technologies.

Biodiesel is the first advanced biofuel in large-scale commercial production. Biodiesel produced from domestic soybean oil is assumed by the EPA to reduce GHG emissions by 57% compared to petroleum diesel fuel, and the EPA's lifecycle analysis recognizes that the GHG reduction could be as high as 85%. (See <http://www.epa.gov/otaq/renewablefuels/420f10006.pdf>.) In the US, biodiesel production is now expanding rapidly (see http://www.biodiesel.org/pdf_files/fuelfactsheets/Production_Graph_Slide.pdf). In 2005, production was 75 million gallons; in 2007, 450 million gallons; in 2008, approximately 700 million gallons. By 2011, 1 billion gallons of biodiesel will be produced. An assessment of the resource available to produce biodiesel indicates that feedstock available today could produce more than 1.7 billion gallons per year.

Intermodal

Convenience and cost are the key factors that determine the mode of transportation for the shipment and distribution of goods. In New York State, the predominant method for transport of freight is by truck, with up to 90% by weight shipped by truck. Truck transportation is the most energy and GHG intensive modes of the movement of freight. A key challenge to reducing GHG emissions in the transportation sector is then to reduce emissions from truck transport of freight. This can be most readily accomplished by reducing GHG emissions from trucks and/or shifting freight to other modes of transport with lower emissions. New York State will have to investigate policy options to bring about modal shifts. These would include:

- Financial assistance to develop more efficient organization of supply-chains, including advanced logistics capabilities and optimal positioning of trans-shipment points and distribution centers.
- Increasing fuel and economy standards for trucks, speed limit reduction/enforcement, and development of anti-idling policies and electrification of rest-stops.
- The development and adoption of advanced technologies, particularly the development of no or low net-carbon bio-diesel fuels and waste heat recovery systems to power air conditioning/electronics.
- Reducing congestion by increasing non-truck modes of transportation; provide incentives and build infrastructure to encourage switching from truck to rail or water transport.

Aviation

Emissions reductions in the aviation sector can come from advances in three areas: improved efficiency through advances in technology, development, and adoption of suitable bio-derived fuels, and improvements to operations and air traffic management.

Significant emissions reductions in the aviation system will come from new composite materials that result in airframe weight reductions, as well as improvements to engine design. For example, as much as 50% of the primary structure of the new Boeing [Dreamliner](#) is made from advanced composite materials. Coupled with advanced engine designs, this will increase fuel efficiency as much as 20% over similar sized aircraft, while permitting air speeds characteristic of the fastest wide-bodies, mach 0.85.

The National Academies' [Airports Cooperative Research Program](#) is examining alternatives to fossil fuels, as is a [coalition](#) that includes the Federal Aviation Administration. [Industry interest](#) in the subject is growing. Currently, new biofuels – “biojet” are being developed for the military. This represents a significant opportunity for reduction of net carbon emissions

from the aviation sector if a sufficient supply of biofuels can be developed for wide-scale adoption and use.

Changes to [air traffic management](#) are expected to lead to ~10% reductions in fuel use, through better management of holding patterns, more efficient take-off and landing trajectories, and minimization of suboptimal routes. Switching modes of travel can reduce emissions, too. Many short-distance flights could be replaced by inter-city high-speed rail; for example, between New York City and Albany, as well as Buffalo.

Serious Challenge: Electricity Supply

Electricity generation is currently among the largest sources of GHG emissions and is projected to remain so under the BAU case. New York's current electricity generation system is a diverse mix of primary energy sources, with about 53% of net generated electricity coming from fossil fuel-fired electric generating units. With a diverse resource mix and a solid base in renewable energy, the state's electric sector is expected to contribute approximately 75.5 million tons of CO₂e to the GHG emissions inventory in 2050

The electricity sector presents a serious challenge for a set of reasons:

- *All mitigation scenarios place increased demand on the electricity sector.*

All three 80x50 scenarios assume total electricity demand in excess of 400,000 GWh, a 50% increase over the BAU case. This is typical of mitigation strategies – for example, see the results of the [Global Technology Strategy Project](#). The reasons are several. The most important is that it is much easier and more cost effective to manage any residual carbon emissions at a central electric generation facility than in highly distributed sources like vehicles or buildings. In the 80x50 scenarios, energy demand is driven to electricity by the almost complete conversion of the building sector to electricity, the substitution of electricity for liquid fossil fuels as an energy carrier in the transportation sector (most notably in the Yellow and Ultraviolet scenarios), and a general shift from fossil fuels to electricity in the industrial sector.

The flexibility of electricity as an energy carrier has led to continued growth in its use. The electricity sector has been well studied, and many technological improvements are made every year. These improvements are quite important: efficiency improvements in the conversion of energy stored in fossil fuels to electricity has a direct impact on the capital cost of all electricity generation resources. Even more important, improvements in the efficiency of end-uses of electrical energy reduce total demand for electricity. The scenarios for each of the major end-uses begin with an assumption of large improvements in end-use efficiency, ranging from 20-30%. Generally, it's expected that the electric generation sector could be decarbonized more easily than distributed uses of energy could be.

- *Renewable resources within the state are not adequate to meet the challenge.*

The major renewable sources of electric power that are carbon free are wind, solar, and hydropower. With the exception of large hydroelectric facilities, these resources are distributed: they collect a local resource. Moreover, in comparison with, for example, a large thermal electric facility like coal or nuclear, they generate far less energy per unit of land. The Yellow scenario includes practically all of the available renewable energy resources in the state, and it includes only resources from within the state. The renewables are over and above the renewable sources assumed to be integrated with buildings.

Wind is a relatively mature technology, and it's relatively easy to estimate how much wind energy is available. The current analysis includes both on-shore and off-shore wind resources. On-shore wind deployment is increasing around the world, but every deployment faces challenges. The first is the actual siting of the turbines, which is often resisted locally for aesthetic and environmental reasons. Second, wind is an intermittent resource and places special demands on the grid, as discussed below. The scenarios are fairly optimistic about success in siting turbines, and they assume wind power's straightforward integration into the grid (as estimated in a [2003 study](#)). They also assume that the current 873 GWh of wind can be expanded to 42,000 GWh by 2050, meeting just over 10% of total projected demand.

Solar is a far less mature technology in terms of both efficiency of conversion and experience with actual installation. The Yellow scenario assumes that 100,000 GWh of demand will be met by grid-installed solar (~25% of 2050 demand); currently in New York the value is zero. This makes the Yellow scenario quite aggressive in several regards. First, this amount of solar energy requires a large amount of land, probably far more than is commonly assumed. For the current generation of solar PV sited in New York, it would take about 1% of the area of New York to generate 100,000 GWh of electricity. Second, it requires a massive improvement in the ability to manufacture photovoltaic (PV) devices. Most current solar technology is based on silicon, and despite large increases in PV cell production, global consumption of silicon for solar applications only recently passed consumption of silicon for semiconductor devices such as computers. Without low-cost, mass production of solar cells on the scale of products like paper or steel, large-scale deployment of solar energy is unlikely. Finally, solar, like wind, is an intermittent resource with special requirement for integration with the grid.

New York has significant hydropower resources, thanks to Niagara/Horseshoe Falls and the St. Lawrence Seaway. Further upgrades and expansions, with a small component of new dams, could significantly increase electric output to the grid and reduce GHG emissions. The Yellow scenario assumes that 10,300 GWh of hydropower will be added to the 25,500 GWh, satisfying nearly 10% of projected 2050 electricity demand.

In summary, the relatively aggressive goals included in the Yellow scenario, which are incorporated in the other two scenarios, meet less than 50% of projected 2050 demand, and indeed in the future they may not be met. But other sources of renewable energy might improve the prospects of success. The largest is probably offshore wind. In addition, full-scale testing of kinetic, in-river hydropower applications is under way in the East River and St. Lawrence River. These projects and maximum build-out were not considered in our analysis, but they could add slightly to the total hydropower package of emission reduction technologies and strategies.

- *Low carbon-emitting central generation options all entail serious issues.*

The discussion of renewable electrical energy options above underscores the fact that demand for central generation of electricity will continue. This demand must be met with low-carbon or no-carbon conversion technologies. Currently in New York, large central generation relies on fossil fuel and 42,500 GWh of nuclear power. Options considered in detail in the scenarios are expanded use of nuclear generation and use of fossil fuels with carbon capture and storage (CCS).

The future of nuclear power generation is uncertain, but nuclear power could satisfy a good portion of a future electricity demand or hydrogen production demand (as discussed above). All of the scenarios assume a continuation of the existing level of nuclear power generation; each takes a different approach to nuclear. The Yellow scenario meets the low-carbon generation option without expanding the current nuclear fleet. The Deep Blue scenario assumes expansion of nuclear power generation by 2 new plants that would generate 25,000 GWh, not counting the additional reactors required for hydrogen generation. The Ultraviolet scenario expands the nuclear supply of electric power by 118,000 GWh, meeting a total of 40% of 2050 electric demand with nuclear power, comparable to the amount planned by Japan.

The scenarios do not speak to the resolution of specific issues associated with nuclear power. Expanding nuclear power will require substantial capital investments and federal loan guarantees. It would require investment in scientific research into and technological advances in alternative fuel cycles and nuclear waste management. It would require public acceptance of license renewals for existing nuclear power plants, expansion of current plants, and siting of new plants.

Fossil fuel combustion with CCS is a significant component of all three scenarios, accounting for 190,000 GWh of energy in the Yellow scenario, 170,000 GWh in Deep Blue, and 70,000 GWh in Ultraviolet. Both coal (IGCC) and natural gas are included in differing amounts in the scenarios. While important in implementation, the fuel choice is non-substantive in comparison with other challenges associated with CCS. They include efficiency of capture and storage, establishment of storage reservoirs, and construction of infrastructure to transport CO₂ from its point of generation to the point of storage. Notably, CCS is not yet commercially available and in fact has not yet been successfully

demonstrated on a commercial scale. Moreover, the regulatory scheme that would govern it remains to be defined, and the capacity for large scale CCS in New York is not presently known.

Probably the most important CCS challenge is efficiency of capture and storage. The scenarios assume a capture efficiency of 90%, with the electricity sector contributing 24, 13, and 10 MMT CO₂e for the Yellow, Deep Blue, and Ultraviolet scenarios respectively. For the latter two scenarios, which do meet the 80x50 goal, CCS still produces 20-25% of total emissions. The improvement of CCS technology to, for example, 99% would significantly reduce emissions.

Storage and transport of CO₂ present closely related issues. The capacity to store CO₂ is not homogeneously distributed throughout the state. Further, little is yet known about the suitability and capacity of those sites to store CO₂. There will be a trade-off between siting of generation sources and siting storage facilities. Certainly, concentrating emissions sources near large-capacity storage reservoirs would simplify implementation and reduce costs. But it could also further increase the burden on the grid. [NYSERDA's studies](#) of New York's potential for CCS are important to defining the long-term potential.

Finally, it should be noted that as 2050 approaches, nuclear fusion may become a viable zero-carbon source of electricity. The scenarios assume it won't be sufficiently well developed to meet energy demand in 2050, but as the State looks beyond its 2050 target to continuing emissions reductions, this technology may be important. Decisions made between now and 2050 can impact its availability in the long run.

- *Infrastructure for electricity transmission and distribution must evolve to meet demand and other services the grid must provide.*

Fortunately, growing demand for electricity is accompanied by substantial research into and development and deployment of new technologies, which are shaping the grid of the 21st century – and at a time when capital improvements to New York's aging grid infrastructure are needed. The smart grid will deliver substantial benefits: greater reliability, enhanced security, "smarter" use of information technology, integration of renewable power generation, better storage technology, and sophisticated demand-management strategies. The ability to manage demand can yield another benefit: avoidance of the huge costs of building more power-generating plants.

The 80x50 scenarios assume three significant demands on the grid. One is the need for increased capacity to carry energy. The capacity increases can be met in two ways. The most straightforward is to install higher-capacity transmissions lines and to increase capacity through upgrades to substations, transformers, and distribution lines. Since all three scenarios call for a 50% improvement in transmission and distribution (T&D) efficiency (which contributes as much to emission reductions as all of the hydro

enhancements), the upgrades will both increase capacity and reduce T&D losses. Another method is changing from conventional T&D lines to high-temperature superconductors. This technology both increases capacity and decreases losses, and it's already employed in two locations in New York State. However, it's complex to manufacture, and manufacturing capabilities must be radically scaled up and costs shrunk before it can be widely deployed.

The second demand on the grid arises from reliance on large amounts of solar and wind: their intermittency must be managed and compensated for. As intermittent loads grow, this becomes a larger and larger problem. In general, the approach been viewed as a question of "what do you do when the sun goes down, or the wind stops blowing?" This implies the availability of a backup energy resource. Because baseload power from thermal resources (nuclear and fossil with CCS) performs best if it operates continuously, increasingly the view is that energy storage might be the best option for intermittent sources.

Hydro resources have some limited storage capacity, allowing their output to be increased when demand grows. However, without "high" dams like those in western US states, this storage is limited. NYSERDA is studying the potential of below-ground compressed air storage potential in New York. The next step is to introduce storage technology, such as batteries, or in the long run, superconducting magnetic energy storage (SMES). This kind of storage has the added value of serving as a convenient means of helping to manage transients in the system, as well. Managing storage to compensate for intermittency will be greatly enhanced by incorporating information technology into the smart grid.

The smart grid also facilitates another strategy for managing intermittency: demand response, in which loss of generation is compensated for by a sophisticated demand-reduction strategy that targets flexible and non-essential loads, shutting them off for a short period of time. These loads can be at the commercial and industrial level, but recent and ongoing demonstrations also show success in the residential sector through use of smart meters and smart appliances.

Finally, the changing mix of end uses on the demand side will alter the temporal demand for electricity on time scales ranging from daily to seasonal. In general, this is a design and load-dispatch problem. What generation resources do you bring on, when, to minimize the cost of generation? To satisfy peaks in demand with the more-expensive generation resources and, through pricing strategies, encourage end-users to not use resources during peak demand periods? Switching of peaks among seasons, from summer peaking to winter peaking, for example, can create resource mismatches for resources that may have a strong seasonal variability, such as hydro and solar.

The scenarios assume the largest new demand will come through vehicle electrification. Studies have shown that smart electronics in, for example, PHEVs can manage that demand to fill in periods of otherwise lower demand. This allows baseload plants to

operate more or less continuously, with consequent greater efficiency. Charging the PHEV “appliance” can also become part of the demand-response network used to manage intermittency – another benefit of the emerging smart grid.

Challenge: The Building Sector – Residential & Commercial

A critical challenge to reaching the 80x50 goal is in the performance of residential and commercial buildings. Reaching mid-century GHG reduction goals will require that buildings function with minimal or no net-energy input (input from the electric grid or from onsite use of high-carbon fuels). New residential, commercial and industrial building systems will need to significantly reduce, and eventually eliminate, onsite fossil fuel combustion for space heating, water heating, cooking, and other needs, and supply electricity through onsite generation from low-carbon energy sources.

The strategy suggested in this vision requires that buildings function with minimal or no net-energy input from onsite use of high-carbon fuels and that to the extent possible their energy demand not be shifted to the grid.. These new residential, commercial and industrial building systems will reduce, and eventually eliminate, onsite fossil fuel combustion for space heating, water heating, cooking, and other needs, and will supply electricity through onsite generation from low-carbon energy sources.

The relationship of the building sector to other sectors is a critical aspect of the 80x50 challenge. These relationships fall within four broad areas:

- End uses: Residential and commercial buildings represent a growing sector of energy demand. This demand is a central part of the standard of living we enjoy. An example is the growing use of personal electronics in residences and the development of large datacenters that support the new internet enabled economy, particularly the global financial industry based in New York. The critical first step in any carbon reduction strategy will be increasing the end use efficiency of the equipment and devices within structures. Reductions of 30% in each electricity and natural gas use is rather straightforward through the adoption of more efficient end-use technologies, such as more efficient lighting, space heating/cooling, water heating, computers, and televisions – as well as through the use of modern controls.
- Structures – A substantial component of the energy demand in the buildings sector is for space conditioning. End use efficiency has an important impact on this demand, particularly in the commercial sector where the cooling demand created by waste heat from devices and equipment. In New York the challenge of structures is exacerbated by the fact that much of the building infrastructure already exists. This will lead to important challenges in improvements of the performance of building

envelopes and the creation of cost effective retro-fit options for key building systems such as windows and increased sealing and insulation.

- Distributed generation – One real option for building is the promise of distributed generation. The use of both photovoltaics and passive solar heating as well as the exploitation of geothermal resources through such technologies as ground source heat pumps offers real promise. The greater the contribution of these technologies to both efficiency and meeting electric demand the less the buildings sector will contribute demand to the already growing burden on the grid. There are many policies options that can help reduce the capital costs barrier could be strong enablers of broader adoption of distributed generation technologies in residential and commercial sectors.
- Communities and the promise of smart growth – Probably the most important trend will be the increased view of the buildings sector as a component of communities. Many of the elements above are even more valuable when one considers collections of structures and seeks to manage energy for these aggregations. Distributed generation for communities can include wind and local biomass conversion for heat and power. The community can become part of a micro-grid that not only effectively manages the electric demand of the community but also can be the basis of using the community as a dispatchable demand response resource for the wider grid. Finally, if the communities take on the “smart growth” approach both in new construction but also in re-development, the communities themselves can have appositive impact on other sectors, most notably transportation.

There has been extensive work on energy efficiency in buildings, done by the [World Business Council on Sustainable Development](#), [the National Academy of Science](#), the [Pew Center on Climate Change](#), and [Lawrence Berkely National Laboratory](#), which offer key data and insights to the energy savings potential. A difficulty in comparing the energy efficiency potential across studies is the variation in methodologies and measures within each of them. However, there are some common themes worth noting.

BOTTOM-LINE ISSUES AND CONSIDERATIONS

The scenarios that inform the visioning process can be further manipulated to yield more insights into interrelationships among mitigation strategies for various sectors. But even at present, and the benefit of insights and knowledge gained at the January 5 visioning workshop and from yet other sources, it's clear that major decisions are necessary to achieve the 80x50 goal.

Many of those decisions must be made sooner rather than later, as they affect long-lead-time matters such as infrastructure investments and research and development strategies that can help or hinder progress. Moreover, the early adoption of some measures won't preclude later adoption of others. Thus, identifying pivotal future decisions and sequencing them becomes a serious challenge in its own right.

The text below discusses issues that follow from the discussion of serious challenges above, and that emerged from the visioning process and other sources. Some concern single economic sectors; some span two or more. While it can be difficult to differentiate technical issues from policy issues, we've tried: the points immediately below are primarily technical in nature; policy considerations follow.

Technical considerations

- Gains in energy efficiency are critical to achieving a low-carbon future. The scenarios don't specify mechanisms, technologies, or practices necessary to achieve these gains, but their importance is clear.
- Very soon, a risk assessment table for critical technologies, such as CCS, nuclear, and solar, should to be developed. This table would highlight the barriers to and compare the types of uncertainty associated with each technology, facilitating the identification of both policy measures and research investments.
- Electrification is an essential strategy, too, and a move to electrification is consistent with the energy needs of a 21st-century economy based on information technology, biotechnology and nanotechnology. If New York's demand for electricity nearly doubles by 2050, a number of issues arise. For one thing, electrification transcends selecting non-carbon emitting central generation technologies and arranging for their siting and financing. Demand on transmission and distribution systems will increase, too. This means that ongoing planning for the smart grid and associated technologies must be part of the Climate Action Plan strategy.

And growing demand will alter not only the amount of electricity needed but when demand peaks, on timescales ranging from daily to annually. How the load duration curve, one measure of changing demand, is managed will be an important part of the smart grid. This may include the use of storage to facilitate handling of larger quantities

of intermittent renewable resources, and the use of active demand management technologies like demand response.

- Electrification of buildings could create a stranded asset in the gas distribution system. The existing infrastructure for gas and its continued expansion may create a structural barrier to the goal of reducing highly distributed point sources of GHG emissions. On the other hand, pipelines moving CO₂ from gas combustion facilities to storage reservoirs may be co-located along rights of way, provided they are appropriately located.
- All scenarios call for the phase-out of fossil fuel generation that free-vents carbon to the atmosphere. The schedule for retiring or converting existing facilities thus becomes an issue.
- Similarly, existing nuclear power plants are on the critical path for a future that continues to rely on nuclear power. These plants would have to be replaced or re-licensed. If relicensed, it would probably be for a maximum of 20 years; they'd then be replaced.
- Nuclear and/or fossil fuel combustion with CCS, which is largely undemonstrated, are important for decarbonization of centrally generated power. Both require long lead times and large capital outlays. CCS also requires significant infrastructure for storage, which will include site selection and certification as well as some pipeline infrastructure. The regulatory scheme that would govern siting and operations of CCS facilities and storage locations remains to be defined.
- The transformation to a hydrogen economy would require a new infrastructure for producing and delivering hydrogen to consumers. The development of gas-cooled, high-temperature nuclear reactors to produce hydrogen would require new plant designs, which would require licensure. Safety regulations for transportation and storage of hydrogen would also be needed.
- In our scenarios we've included some technologies that are emerging but not yet commercial, such as CCS. Others are unproven, such as large energy storage. We omitted nuclear fusion, an unproven technology, and direct air capture of carbon dioxide, which is speculative at this time. These all have theoretical potential to help achieve the 80x50 goal, but the timeline for making changes requires technologies that are in development today, and ready for deployment at scale within approximately a decade. The current [international roadmap](#) for fusion would have the first demonstration reactor online in about 2040.
- The scenarios assume complete success; for example, total conversion of the building sector to electricity, or to net-zero carbon emissions. Inevitably, there will be "leakage," which will place further limitations on emissions from other sectors or technologies.

- Renewable resources play a major role in all three scenarios. But even with expected gains in renewable energy technology efficiencies, the state's renewable resources can't meet all of projected future energy needs. And, distributed resources used on a large scale would require large tracts of land for solar arrays, wind farms, and biomass cropping. The scenarios assume all renewable resources would come from within the state. This is consistent with the State's desire to develop its own resource and energy industry. But out-of-state renewable resources could be used, too, and perhaps in some cases more cheaply. Opening the market could take pressure off in-state only resources.
- Sustainable biomass is a limited resource. What's the best allocation for its use? Should it be used for transportation (as in our scenarios), to heat buildings, or for power with CCS, which could create a carbon sink?
- The grid-installed solar electric assumption in the scenarios is quite optimistic and may not be met without significant energy conversion improvements in photovoltaic panels and systems. Distributed solar awaits gains in scalability, reductions in cost, and the creation of large-scale installation capabilities. The scenarios don't include some renewable technologies that may be fungible and that could help reduce emissions, such as geothermal and hydrokinetic energy sources.
- The transportation sector is an extremely large, diffuse source of GHG emissions. All of the scenarios largely call for eliminating gasoline and diesel as energy carriers and replacing them with bio-fuels, hydrogen, or electricity. The sector is diverse, with each of the subsectors – light duty vehicles (LDV), heavy duty vehicles (HDV), mass transit, and aviation – having its own special needs. Key issues include these:
 - Transportation options create an infrastructure demand that must be accounted for in planning. The current network of fueling stations for LDV and HDV is pervasive, with one or more fueling station in virtually every community and neighborhood in the state. Pushing vehicles to electricity adds demand to the distribution system, while a hydrogen-based vehicle system would necessitate replacement of key components of this extensive refueling network.
 - The specifics of how to reduce VMT aren't addressed in the scenarios. They're important: e.g., reducing VMT means increased demand on and expansion of mass transit, as well as potential impacts on community design, development, and redevelopment.
 - Significant improvements in vehicle fuel efficiency are important to the mitigation scenarios. Whether national standards will be sufficient to drive this change is questionable.
- The state's residential and commercial sectors are a major source of emissions, and the scenarios call for substantial improvements in energy efficiency and the source of energy used for space conditioning, hot water, and cooking. At the January

workshop, the point was made that many building professionals have little concept of how much buildings contribute to GHG emissions, and how little it costs to mitigate them. New York City's new [Green Codes](#), a major effort commissioned by the Mayor and City Council Speaker, may offer a useful guide for other cities in the state, for starters.

But even if all building owners, managers, and tenants were committed to greening the existing building stock, the workforce needed to install energy retrofits may not be adequate to the job: training may be required, along with financing schemes that facilitate retrofits.

- All three scenarios assume use of distributed renewable energy in the building sector. This resource is over and above transmission-connected resources accounted for in the electricity sector. The Deep Blue and Ultraviolet scenarios call for the residential sector and commercial sector to be zero emissions, not net-zero. If the strategy evolves to a net-zero standard, other emissions not accounted for in the scenarios will have to be offset.
- Serious methodological questions must be addressed. For example, how well understood are interconnections among complex physical systems—the networks of energy inputs and feedback loops—that drive emissions? That link energy use and water use? Should estimates of GHG emissions include embedded energy, which produces emissions beyond the state's borders? How far should lifecycle analyses go?
- With a goal of 51 MMT CO₂e, even small sources of emissions become important. Emissions reductions strategies for several sources (e.g. asphalt production, SF₆ leakage, etc.) are not immediately clear. Work is needed to develop strategies for management of emissions from all sources.
- *Interdependencies.* The interdependencies, and consequent vulnerabilities, of transportation, water, energy, and communication systems have direct consequences for system performance and thus for climate change adaptation and mitigation. System managers and operators must be helped to understand and manage those interdependencies.

Policy considerations

- *Incipient policy conflicts and synergies.* The Climate Action Plan has pervasive ramifications for the state's economy and social fabric. Many existing State policies may facilitate or hinder achievement of the 80x50 goal. Policies made by other states and the federal government can affect New York's ability to pursue its chosen path. For example interstate commerce (tourism, freight, and aviation) is shaped by federal policy. Large-scale renewable energy involves significant land-use choices,

for siting of wind and solar facilities and use of biomass resources; local choices and policies may affect the State's ability to meet its renewables goals.

- *Policy gaps.* What regulatory scheme will be required to cover the siting for CCS facilities, pipelines, and storage sites, and the permitting of CCS operations? For gas-cooled, high-temperature nuclear reactors that would produce hydrogen? For new technologies yet to emerge? Designing and implementing regulatory "infrastructure," so to speak, might be no small undertaking in its own right.
- *The need for partnering.* Related to policy conflicts and synergies is the great need for partnering among all levels of government and between the public and private sectors, with regional collaboration being a point strongly urged at the January 5 workshop. The inclusiveness and openness already demonstrated by the NYS Climate Action Council and the State's many other climate and energy initiatives, including the State's aggressive partnering with local governments through the [Climate Smart Community Pledge](#), augurs well for this. Obviously, close partnering with the business community will remain a long-term necessity.
- *Long-term consequences of near-term decisions, and lack of decisions.* Decisions made, and not made, about matters that require long lead times, such as major infrastructure projects, and that have long-term consequences, such as land-use policy and a commitment to CCS, cast long shadows into the future. Whatever the choice of low-carbon sources of electricity (CCS, nuclear, solar) and of energy carrier for transportation (electricity or hydrogen), the electricity sector *must* plan for the expansion of the grid and improvement of transmission and distribution. Some early actions, such as improving energy efficiency, have value regardless of other choices made; others may have value only in relation to specific choices of technology, such as development of CCS infrastructure. It's important to remember that achieving a low-carbon future requires a portfolio of actions, and that "easy" decisions aren't substitutes for hard ones.
- *The rate at which policies drive change matters to success.* But this important factor is difficult to manage. The Climate Action Council is working in a field in motion, as technologies evolve, economic conditions change, and other parties, including the federal government, make decisions that have consequences for New York.
- *Stranded capital investments.* Practically all energy-related technologies require both infrastructure and capital investment from the private sector, and those investments are generally large. If they are foreclosed because of decisions that support the 80x50 goal before they've delivered a full return on investment or reached the end of their useful lifetimes, the result will be stranded capital investments – both a major hidden cost of carbon mitigation and a source of resistance to future change.
- *Investments by the State.* The current performance of many technologies assumed by the mitigation scenarios – such as PV, offshore wind, large-capacity/low-cost

batteries, PHEVs, CCS, zero-energy commercial buildings and LEDs – is inadequate to meet the 80x50 goal. Those technologies will require investment to boost performance. Sources like DOE-National Lab Roadmaps and the National Academies' study, [America's Energy Future](#), identify step-function improvements in technology and major investments in infrastructure needed to achieve a low-carbon economy.

- *Motivating change.* The scenarios make no explicit assumptions about individual behavior. How to motivate individuals to modify their energy consumption and patterns of use, drew considerable interest at the January workshop, and warrants the attention the State Climate Action Council.

CODA

Insidiously, carbon emissions are cumulative: they persist in the atmosphere for up to thousands of years. This means that as levels of emissions grow, reducing them to levels deemed acceptable becomes ever harder. And because New York is already more energy-efficient than most states, reducing emissions from what is already a low baseline is harder, still.

Against this physical reality, the momentum of *business as usual* is not to be underestimated: it's one of the most powerful forces in the world. And yet, the nature of *business as usual* continually evolves. The "installed base" of current energy technologies represents trillions of dollars in sunk costs and powerful special interests. Fossil fuels are cheap, abundant, and convenient. Options for scaling up alternatives to them, affordably, are not yet in hand. Yet history tells us that technologies, and markets, continue to change. The brutal realities of fiscal deficits are certain to constrain important efforts to achieve the 80x50 goal. And yet they also make the very real economic opportunities generated by that goal even more compelling.

Notably, the assets and advantages that the State enjoys can be game-changers, too. Executive Order 24 is soundly and sensibly conceived. The Climate Action Council's approach to its task is exemplary. It enjoys the benefit of committed top-down leadership; many motivated state employees who possess technical expertise, policy savvy, and insight into how government and the political system work; a broad-spectrum approach that engages a large number of committed stakeholders in the NGO and private sectors; and a deep commitment to achieving environmental justice.

Crucially, the Council is rapidly gaining insight into the staggering magnitude of the challenge it has been tasked to address and the nature of the strategies it can employ.

Over coming decades, New Yorkers – long celebrated for being tough, resourceful, and creative – may well prove to be the equal of the 80x50 challenge. Every megaton of GHG emissions avoided will be a gain, and the societal and economic transformation achieved in vigorous pursuit of sustainability will create a future for our children and grandchildren and generations beyond that is *better* than the present we inhabit.

APPENDIX A

Supplemental Information on Methodology & Data Sources for the Baseline Forecast of Energy Demand and the “Business as Usual” Case

The input to the macro coupled-sector modeling is the baseline projection for energy demand by sector and fuel type in 2050. These values were estimated by a constant growth (% per year) extension of the modeling conducted in the development of the [New York State Greenhouse Gas Emissions Inventory and Forecast](#) for the [2009 State Energy Plan](#), which estimated the GHG emissions by sector and fuel type to 2025.

Forecasts of petroleum and coal use for residential, commercial, industrial, and non-highway transport sectors were based on U.S. Energy Information Administration (EIA) forecasts for Mid-Atlantic fuel demand, along with natural gas projections provided by Energy and Environmental Analysis, Inc. (ref: Energy Demand and Price Forecast, [2009 State Energy Plan](#)).

Forecasts for fuel use for the electricity sector and net imports of electricity were based on output from ICF International's Integrated Planning Model® (IPM), an electricity sector modeling software used to support the development of the 2009 State Energy Plan. Energy demand by sector and fuel type was modeled to 2025. From 2025 to 2050, a constant annual rate of growth or decline was assumed. In addition, emissions projections for 2025 and 2050 are also estimated and presented in Table 2 above. These projections include estimated emission reductions due to RGGI and partial implementation of [New York's 15x15 energy efficiency goal](#).

Forecasts of NYS vehicle miles of travel (VMT) were estimated from historical NYS Department of Transportation VMT data (https://www.nysdot.gov/divisions/policy-and-strategy/darb/dai-unit/ttss/repository/vmt_0.pdf). NYDOT estimates that VMT will continue to grow at a 1.1% per year growth rate out to 2030, and is assumed to grow at this pace to 2050. The annual rate of growth of VMT was 2.5% between 1975 and 1990, and 1.7% between 1990 and 2005 (See [Strategies for a New Age: New York State's Transportation Master Plan for 2030](#).) On-highway diesel and gasoline fuel use was based on NYS VMT along with the Department of Energy's Energy Information Agency-projected vehicle economy, and was the basis the estimate of emissions from the transportation sector.

Finally, non-fuel combustion GHG emission forecasts for the industrial sector were based on the projected growth of New York industries. These forecasts were created using Policy Insight® version 8.0, macroeconomic modeling software from Regional Economic Models Inc. Estimates for emissions from hydrofluorocarbon (HFC) refrigerant substitutes are scaled from EPA projections for national emissions by New York State's relative use of air conditioning, refrigerators, and freezers. Emissions from electricity transmission and distribution were assumed to continue to decline, following the long-term historical trend.

A more detailed explanation of the forecasting methods can be found in the NYS State Energy Plan Energy Demand and Price Forecast Assessment. GHG emission forecasts are in large part based on these energy-use forecasts. A more detailed explanation of the sources and methodologies for GHG emissions can be found in the [New York State Greenhouse Gas Emissions Inventory and Forecast](#) for the [2009 State Energy Plan](#).

Appendix B

GHG Emissions Scenario Assumptions

Sector	Yellow	Deep Blue	Ultraviolet
Transportation	<p>Smart growth reduces VMT Demand 10% for LDV Fleet mix composed of CV/HEV/PHEV* = 30/30/40 CV reaches 37 mpg; HEV miles at 50mpg 95% of VMT for PHEV are all-electric 50% of HDV miles switch to freight transport by rail 30% efficiency gains in aviation</p> <p>~51.3 MMT CO₂e</p>	<p>Smart growth reduces VMT demand 40% for LDV 100% of VMT for LDV from hydrogen (nuclear-based) @65 mpg equivalent 50% HDV VMT switch to freight transport to rail; 40% of balance of miles from biodiesel 30% efficiency gains in aviation, 50% reduction of aviation emissions from biofuel</p> <p>~15 MMT CO₂e</p>	<p>Smart growth reduces VMT demand 40% for LDV 95% of VMT from LDV are all-electric miles Balance of LDV VMT 50 mpg with in-state E85/biodiesel 50% HDV VMT switch to freight transport to rail 30% efficiency in aviation sector; 50% reduction of aviation emissions from biofuel</p> <p>~20 MMT CO₂e</p>
Electricity	<p>25% electricity efficiency in Residential 25% electricity efficiency in Commercial 10% electricity efficiency in Industrial Minimize combustion; what is left switches to IGCC, NGCC w/ CCS Max hydro, wind No new nuclear NO NEW OUT OF STATE RENEWABLE ELECTRICITY</p> <p>~24 MMT CO₂e</p>	<p>Significant efficiency gains as in Yellow Scenario Eliminate all combustion Maximize hydro 30% from carbon-free (nuclear [+2 new plants producing 25K GWh] + hydro) 30% from renewables (utility-scale solar (100,000 GWh), max wind) 40% from NGCC and CCS (@90%) H2 via electrolysis of high-temperature steam using high-T gas-cooled reactors (5-8 plants) NO NEW OUT OF STATE RENEWABLE ELECTRICITY</p> <p>~13 MMT CO₂e</p>	<p>Significant efficiency gains as in Yellow Scenario Maximize hydro, max wind 35% from carbon-free (nuclear [15 new nuclear plants; 24 total], max hydro) 35% from renewables (utility scale solar (100,000 GWh), wind) 17% from NGCC and CCS (@90%) 35%- 40% energy demand in Res./Comm from local solar NO NEW OUT OF STATE RENEWABLE ELECTRICITY</p> <p>~10 MMT CO₂e</p>
Residential	<p>20% efficiency gains in energy demand for heat/hot water 10% of electricity needs met from local solar Reduce combustion by 70-80%</p> <p>~7.5 MMT CO₂e</p>	<p>30% reduction in energy demand through efficiency 50% delivered gas/liquid fuels from biomass 40% of balance of energy demand left met by local solar generation Balance to energy demand from grid</p> <p>ZERO MMT CO₂e</p>	<p>50% reduction in energy demand through efficiency Eliminate all combustion of gas, oil 40% of balance of energy demand met by local solar PV</p> <p>ZERO MMT CO₂e</p>
Commercial	<p>Reduce natural gas/oil combustion by 75% 10% of electricity needs met from local solar Balance of energy need shifted to central electricity</p> <p>~4.5 MMT CO₂e</p>	<p>20%-30% efficiency gains 50% delivered liquids fuels from biomass ~30% of electricity demand from local solar Balance of energy need shifted to central electricity</p> <p>ZERO MMT CO₂e</p>	<p>20%-30% reduction in energy demand through efficiency Eliminate all combustion of gas, oil ~ 50% of energy demand from local solar Balance of energy need shifted to central electricity</p> <p>ZERO MMT CO₂e</p>

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<i>Industrial</i>	<p>Eliminate all coke/coal use Reduce natural gas/oil combustion by 50% Switch coke/coal to natural gas Balance of energy need shifted to electricity</p> <p>~14 MMT CO₂e</p>	<p>20%-40% reduction in energy demand through efficiency Eliminate natural gas, oil combustion Eliminate coke at cement/boilers; switch to natural gas Residual of emissions from asphalt, petrochemical, other (8.4 MMT)</p> <p>~13MMT CO₂e EMISSIONS</p>	<p>20%-40% reduction in energy demand through efficiency Eliminate natural gas, oil combustion Eliminate coke at cement/boilers; switch to natural gas Residual of emissions from asphalt, petrochemical, other (8.4 MMT)</p> <p>~13MMT CO₂e EMISSIONS</p>
<i>Other</i>	<p>Eliminate SF₆ dielectric from T/D grid 50% reduction in line leaks in natural gas RRR policy Eliminate HFC leaks Reduce process CO₂</p> <p>~12 MMT CO₂e</p>	<p>Eliminate SF₆ dielectric from T/D grid Eliminate hydrofluorocarbon emissions Eliminate 90% line leaks in natural gas RRR policy to eliminate 100% municipal methane/waste emissions Eliminate HFC emissions</p> <p>~12 MMT CO₂e EMISSIONS</p>	<p>Eliminate SF₆ dielectric from T/D grid Eliminate hydrofluorocarbon emissions Eliminate 90% line leaks in natural gas RRR Policy to eliminate 100% municipal methane/waste emissions Eliminate HFC emissions</p> <p>~12 MMT CO₂e EMISSIONS</p>

CV = Conventional Vehicle; HEV = Hybrid Electric Vehicle; PHEV = Plug-in Electric Hybrid Vehicle; LDV = Light Duty Vehicle; HDV = Heavy Duty Vehicle; VMT = Vehicle Miles Travelled;
 MMT CO₂e = Million Metric Tons CO₂ Equivalent

Appendix G

Electric Vehicle Workgroup Report

Background¹

The transportation sector currently produces 39.5 percent of New York State’s combustion-based inventory of greenhouse gases (GHGs). The gasoline-fueled light-duty vehicle sector is responsible for the vast majority of those emissions. Plug-in electric vehicles (EVs), plug-in hybrid electric vehicles (PHEV), and fuel cell vehicles (FCVs) powered by hydrogen derived from electrolysis, offer the potential to displace a significant portion of this petroleum consumption by using electricity for all or portions of vehicle trips. If this electricity has a low- or near-zero carbon intensity, the carbon footprint from this segment could be nearly eliminated.

The New York Climate Action Council established five Technical Working Groups representing key sectors of the economy. Each Technical Work Group was tasked with providing technical analysis and developing policy options for GHG reductions in each sector. The GHG reduction potential of electrically powered vehicles will be influenced by the policies developed in three sectors: Transportation and Land Use; Power Supply and Delivery; and Residential, Commercial/Institutional, and Industrial Buildings and Infrastructure. The cross-sector Electric Vehicle Subgroup² was established to identify how transitioning to a high penetration of grid-powered vehicles would affect multiple economic sectors and to establish, where possible, a consensus on a comprehensive transition strategy for all sectors.

The Approach

The Cross-Sector subgroup consisted of members from the Transportation and Land Use, Power Supply and Delivery, and Residential, Commercial/Institutional, and Industrial Technical Work Groups. The approach used was: (1) segment the flow of electricity from source to vehicle into five stages; (2) identify the questions and issues in each segment that need to be addressed to achieve significant market penetration of plug-in vehicles with maximum GHG reductions; and (3) research the issues, establish findings, and describe strategies or approaches that address the issues. Where appropriate, the group made an attempt to identify mid- and long-term issues.

In addition to the individual sector perspective and expertise of the Technical Work Group members, the group invited participation and presentations from several outside sources. These included vehicle manufacturers Ford and Tesla and a manufacturer/supplier of charging station infrastructure.

¹ This report was developed by representatives from the Climate Action Council’s Transportation and Land Use (TLU), Power Supply and Delivery (PSD), and Residential Commercial/Institutional, and Industrial (RCI) Technical Working Groups. The report describes cross-sector issues and policies associated with a transition to electric-grid-powered vehicles.

² Subgroup Members: Richard Drake (NYSERDA), Eleanor Stein (NYS DPS), Matt Fronk (RIT), Jamie Van Nostrand (Pace University), Joe Oats (Consolidated Edison), Steve Corneli (NRG Energy), Kerry-Jane King (NYPA), Carol Murphy (ACE NY), John D’Aloia (NYS DPS), Steven Tobias (National Grid), Matt Nielsen (General Electric), Dave Coup (NYSERDA), John Zamurs (NYS DOT), and David Gardner (NYS DEC).

Summary

General: A top priority should be an in-depth analysis of the coincidental overlays of: EV-charging load profiles; future intermittent and non-dispatchable generation growth in New York State; and projected residential, commercial/institutional, and industrial electrical load growth in the state. The findings in this appendix are based on available analysis as referenced in the report.

Power Supply—Generation

- Through the mid-term (2025), New York State has adequate generation capacity to accommodate the maximum (30 percent) anticipated penetration of EVs and PHEVs.
- “Smart charging” to minimize grid impacts will be necessary.
- New York’s current off-peak generation mix provides PHEVs significant GHG reductions, as compared to conventional vehicles. However, to maximize GHG reductions, the transmission grid will need to be near carbon-free.
- Through the mid-term (2025), the state’s transmission grid has adequate capacity to accommodate the maximum (30 percent) anticipated penetration of EVs and PHEVs with smart charging.

Distribution

- Near to mid-term: Local distribution (transformer) upgrades are likely to be necessary.
- Longer term: The large number of EVs requiring quick charge may require local storage.
- Business models, policies, and regulatory actions encouraging smart charging and allowing third-party sale of electricity may be necessary.

Infrastructure

- Building codes addressing Level II and Level III charging in new residential and commercial garage construction will significantly reduce costs.
- Building codes that address garaging hydrogen-fueled vehicles should be part of the long-term solution.
- Policies and regulations should encourage the development of a variety of business models for charging/refueling (battery swap, etc.).

Vehicles

- PHEVs, EVs, and FCVs demonstrating acceptable performance are a reality.
- Vehicles deriving their fuel from the electric grid are likely to become a cost-effective means of achieving carbon-free mobility.

- Near term: Incentives will likely be necessary to induce adoption. Gas may need to reach \$4/gallon and research and development (R&D) will be needed to improve performance and reduce cost before EVs and PHEVs are economically compelling without incentives.³
- Near- and mid-term: Battery vehicles will predominate. The advantages of FCVs having greater range, performance, and quick fill together with lower vehicle cost may compel commercial fleets initially and later private vehicles to invest in localized hydrogen infrastructure based on electrolysis from off-peak carbon-free grid power.

Table G-1. Electric Grid Powered Vehicle—Climate Policy Issues by Category

A Generation	B Transmission	C Distribution	D Infrastructure (Buildings and Facilities)	E Vehicle + End-User
<p>A-1: How much generation is needed to meet the new load?</p> <p>A-2: What CO₂e intensity is required to achieve 80 by 50? How do we achieve it?</p> <p>A-3: What is the desired load shape for EVs to minimize the carbon intensity of required generation?</p>	<p>B-1: Do we have sufficient transmission capacity to meet the new load?</p> <p>B-2: Does this new load create any major reliability issues (e.g., stability, thermal, voltage)?</p> <p>B-3: Are there transmission-level investments that would reduce the carbon intensity of an EV load?</p>	<p>C-1: Do we have sufficient distribution capacity to meet the new load?</p> <p>C-2: Does this new load create any major reliability or infrastructure cost issues (e.g., stability, thermal, voltage)?</p> <p>C-3: Are there legal, regulatory, or policy actions that could reduce transaction obstacles and accelerate a transition to electrified transportation?</p> <p>C-4: Who should pay for any required upgrades? The individual beneficiary or the rate base?</p> <p>C-5: Will fast-fill fueling require distribution-scale stationary energy storage (hydrogen or electric)?</p>	<p>D-1: What charging infrastructure/strategy is needed?</p> <p>D-2: Are changes necessary in retail electricity rate structures? If so, how should they be changed?</p> <p>D-3: What kind of advanced metering is needed?</p> <p>D-4: What land-use issues need to be addressed?</p> <p>D-5: What kind of consumer education is needed?</p> <p>D-6: How do we bring upfront costs down for consumers?</p> <p>D-7: What codes and standards need to be created/updated?</p>	<p>E-1: What charging technologies are needed (e.g., smart charge)?</p> <p>E-2: What battery technologies are most suitable for this application? Are they available and cost-effective?</p> <p>E-3: What vehicle platform(s) seems the most viable? Can EVs meet driver needs, or will we need fuel cell or bio-PHEVs to meet range requirements?</p> <p>E-4: Who will service these vehicles?</p> <p>E-5: What is the rate of advanced low carbon vehicle introduction needed to meet 80 by 50? How do we get more cars “in the pipeline”?</p> <p>E-6: How do we bring upfront costs down for consumers? Are incentives required to overcome the high cost of electric vehicles?</p>

80 by 50 = 80percent reduction in carbon from 1990 levels by 2050; CO₂ = carbon dioxide; EV = electric vehicle; PHEV = plug-in electric vehicle.

³ *Transitions to Alternative Transportation Technologies*, National Academy of Sciences, 2010.

Strategies

A. Power Supply: Generation

A-1 How much new generation is needed?⁴

New York's electric supply is sufficient to meet electric vehicle megawatt (MW) requirements in the near-to-mid-term (2025). According to a National Renewable Energy Laboratory study, "a 50 percent penetration of PHEVs would increase the per capita electricity demand by around 5–10 percent, while increasing total electrical energy consumption (but without requiring additional generation capacity)." However, an increased proportion of low- or zero-carbon generation to displace traditional fossil plants must be brought on line to meet the 80 by 50 goal. This assumes that smart charging will be implemented as grid-fueled vehicle penetration grows. It may be necessary for public policy or rate structures to provide incentives and disincentives to implement adoption.

- Strategy: Near-term and long-term continued support of R&D for renewable technologies, as well as methods to reduce carbon from fossil sources; continued financial incentives/rate structure to encourage low-/zero-carbon generation and off-peak, valley filling charging.

A-2 What electric grid carbon dioxide (CO₂) intensity is required to achieve 80 by 50?⁵

The nation has experienced a significant increase in the carbon intensity of the grid over the past 20 years. Therefore, for the United States to achieve an 80 percent reduction in carbon from 1990 levels by 2050, the country must cut its current rate of 5.8 billion tons CO₂/year to 1 billion tons/year. This equates to approximately a 4 percent reduction each year for the next 40 years.

The carbon intensity of the grid varies significantly as a function of grid load, with off-peak power having the lowest carbon footprint. In New York, the electric grid is responsible on average for approximately 800 pounds (lb) of CO₂ for every MW produced. At this level of intensity, an all-electric car typically produces approximately 0.3 lbs. of CO₂ per mile while a conventional vehicle getting 26 miles per gallon (MPG) produces 0.77 lbs. CO₂ per mile. Therefore, with today's generation mix, an electric vehicle provides on average a 61 percent reduction in CO₂. With the current generation mix, New York State would be unable to achieve the 80 by 50 goal, even if elective vehicles were used for all travel. While off-peak power is less carbon intense and "smart (off-peak) charging" has the potential to provide some benefit in the near term, a high percentage of grid-powered vehicles and a near-zero carbon footprint from the electric grid will be required in order to achieve the 80 by 50 goal

- Strategy: (1) Develop technologies (energy storage, smart charging) and policies (EV electric rates) that promote vehicle charging at times when the carbon intensity of the grid is lowest

⁴ EPRI/NYSERDA, *Grid Impact of PHEVs*, 2010; NREL, *An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles*, Oct. 2006; PNNL, *Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids*, 2007.

⁵ International Energy Agency, "CO₂ Emissions from Fuel Combustion - Highlights," 2009; U.S. DOE, *Annual Energy Review*, Table 12.2, 2009; CARB, *2050 Greenhouse Gas Emissions Analysis: Staff Modeling in Support of the Zero Emission Vehicle Regulation*, 2009.

(i.e., off-peak). (2) De-carbonize the grid to the greatest extent possible. Achieving more than a 60 percent reduction in vehicle-mile carbon intensity from EVs will require a grid with a much lower carbon footprint.

*A-3 What is the desired load shape for EVs to minimize the carbon intensity of required generation?*⁶

EV charging should move to off-peak charging. Conversely, charging immediately upon returning home (4-6 p.m.) should generally be avoided, as this could compete with other electrical loads. Furthermore, moving charging to overnight hours would correlate with the production profile of zero-carbon wind resources in New York (as well as base-loaded hydro and nuclear power).

- Strategy: Create an electricity rate structure with incentives for EV owners to charge during off-peak hours, with the highest incentives during overnight hours.

B. Transmission

*B-1 Do we have sufficient transmission capacity to meet the new load?*⁷

The transmission system will not require added capacity specifically for EV charging because PHEV vehicle adoption is not anticipated to seriously affect generation (MW of supply).

- Strategy: This assumes smart charging and other strategies to shift demand from peak hours. Otherwise, no specific strategy is required, assuming upgrades to the transmission system due to expected load growth outside of EV.

*B-2 Does this new load create any major reliability issues (e.g., stability, thermal, voltage)?*⁸

System reliability could be reduced as a result of a high utilization scenario, as less reserve capacity is available. With smart charging, reliability issues are not expected. With further advancements in vehicle-to-grid (V2G) technology, it is possible that vehicle storage may provide benefits to transmission system reliability. While it appears that PHEVs are much better suited to support short-term ancillary services, such as regulation and spinning reserve, a large fleet of PHEVs could replace a moderate percentage (perhaps up to 25 percent) of conventional low-capacity-factor (rarely used) generation used for periods of extreme demand or system emergencies. Overall, the ability to schedule both charging and very limited discharging of PHEVs could significantly increase power system utilization.

⁶ NYISO, "Alternate Route: Electrifying the Transportation Sector," June 2009.

⁷ KEMA, *Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems*, report for ISO/RTO Council; PNNL, *Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids*, 2007. (Note: KEMA is not an acronym, it is the name of an international testing and certification company.)

⁸ PNNL, *Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids*, 2007; NREL, *An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles*, Oct. 2006

- **Strategy:** Adopting “smart charging” systems that recognize grid emergencies could mitigate the extent and severity of these events. Continue R&D into V2G technology. Explore financial incentives for providing grid support.

B-3 Are there transmission-level investments that would reduce the carbon intensity of an EV load?

The issues of vehicle range, fueling infrastructure, and cost will be challenging. Quick-charge (Level III) electric charging may require stationary storage or other upgrades. Range issues can be overcome with FCVs; however, quick-fill public hydrogen infrastructure would require a major investment. A third option, hybrid bio-PHEV, may be the easiest pathway on the vehicle side; however, low-carbon cellulosic ethanol is not yet a proven option.

- **Strategy:** All of the above options should be developed; all may be needed to meet the variety of duty cycles, first cost versus operating cost constraints, and user needs. In all cases, continuous improvements in vehicle technology will be needed, together with significant long-term infrastructure investment. Public policy should be technology-neutral and, in the near term, focus on low-carbon vehicle incentives, such as feebates for low-carbon vehicles and tax credits and buy-downs for fueling infrastructure.

C. Distribution

C-1 Do we have sufficient distribution capacity to meet the new load?⁹

To achieve the penetration rates required by the 80 by 50 target, some distribution system upgrades will undoubtedly be needed. Because of clustering and a slower penetration rate of pure battery versus PHEV, current analysis indicates that upgrades involving distribution transformers and customer service – not primary feeders or transformers – will be needed at a local level. Impacts can vary greatly from system to system. Some distribution systems have a ratio of customers to service transformers as low as 2 to 1, while others, such as Rochester Gas and Electric, have ratios of 9 to 1. This will result in different impacts on the distribution systems in different distribution systems. In systems that are largely underground, there is some potential for underground cables and transformers to have inadequate cool-down periods at night, should significant load be shifted to off-peak nighttime periods on feeders that are highly loaded during the day. So, although the load growth rate is generally expected to be within the normal bounds of planning activities and load growth, there will be situations requiring special consideration and study.

- **Strategies:** Smart charging, load shifting, and stationary storage all have the potential to mitigate most of the anticipated problems for the next decade.

⁹ EPRI/NYSERDA, *Analysis of Grid Impact of PHEVs in New York State*, 2010; Quanta Technology, “Thoughts and Opinions on the Impact of Plug-in Hybrid Electric Vehicles,” 2008.

C-2 Does this new load create any major reliability or infrastructure cost issues (e.g., stability, thermal, voltage)?

As noted in B-2, (transmission), distribution reliability issues are not expected with smart charging. With further advancements in V2G technology, it is possible that vehicle storage may actually provide benefits to distribution system reliability.

- Strategies: Financial incentives for desired market transformation and disincentives for unwanted behavior will be necessary to accelerate low-carbon vehicle market penetration. Infrastructure investment will also be a necessary element and may require adjustments in public policy and public investment.

C-3 Are there legal, regulatory, or policy actions that could reduce transaction obstacles and accelerate a transition to electrified transportation?

- Strategy: Consider revised tariffs in New York that would allow charging infrastructure providers to resell the electricity they purchase from utilities.

C-4 Who should pay for any required upgrades? The individual beneficiary or the rate base?

It could be argued that the advent of PHEVs is similar to the widespread adoption of air conditioning in the 1960s. The utilities incorporated this new load as a part of their normal planning process, and the cost was added to the rate base.

- Strategy: Costs should not be borne by individual customers. A preferred alternative is to use revenue derived from a broader base to cover the cost of upgrades specific to the supply of electricity for plug-in vehicle charging.

C-5 Will fast-fill fueling require distribution-scale stationary energy storage (hydrogen or electric)?

- Strategy: Since fast-fill charging is likely to be required by a user at a time other than off-peak hours, purchase of the stationary electrical storage may be necessary to minimize negative grid impacts and allow the utilization of excess renewable electricity generated in off-peak times.

D. Infrastructure (Buildings and Facilities)

D-1 What charging infrastructure/strategy is needed?

It seems generally accepted (and reinforced with surveys, PlaNYC, Electric Power Research Institute, etc.) that the most important locations for charging infrastructure are those facilities where vehicles are parked routinely for extended periods, such as home garages or places of work. New business models together with communication and transaction protocols will need to be standardized to allow smart charging that benefits the grid and consumer.

There are potential legal and regulatory barriers or policy choices related to the introduction of electric vehicle charging facilities on private premises and for public use. Under current New York law, all sellers of electricity to end users are electric corporations subject to Public Service Commission (PSC) regulation over rates and practices. New York has three overall options: (1) New York state could exercise this jurisdiction to set prices for EV charging that encourage

electric car consumption and ensure off-peak charging to minimize grid impact (the Michigan approach); (2) the state could lightly regulate or forbear from regulating EV charging, to encourage new entrants and competition (the California approach); or (3) the state could amend its laws to deregulate entirely the sale of electricity as a motor vehicle fuel (to open the EV charging market completely, without any governmental oversight as to price and conditions, while safety and reliability restrictions would remain). Each approach has its own advantages, costs, and risks, and the policy and legal discussion is ongoing.

- Strategies: *First priority*: Standardize physical interconnections (plugs, voltages, etc.) and communications protocols. *Second priority*: Pursue public policy and regulatory actions that support the development of business models that allow the sale of electricity by third parties (non-utility), aggregation of loads for business transactions, private and public investment in publicly accessible vehicle charging, and development and deployment of standardized quick-charge (Level III) technology.

*D-2 Are changes necessary in retail electricity rate structures? If so, how should they be changed?*¹⁰

California's Public Utilities Commission has established special rates for EV charging and off-peak use. Remote-controlled charging could also occur by allowing customers to charge their vehicles at any location and be billed for the energy at a rate determined by the location of the vehicle, rather than at a residential rate.

- Strategy: Establish EV electric rates that encourage vehicle charging load growth that is consistent with minimized negative impact on the grid and that provides positive economic incentives to consumers. PHEV-specific dynamic pricing may be one way to introduce dynamic pricing to consumers while minimizing adverse customer reaction with regard to existing retail loads.

D-3 What kind of advanced metering is needed?

Using advanced meters, vehicle charging would be one of several home energy uses that could be managed through automation. Even simple time-of-use residential meters could provide customers with the incentive and the ability to manage their energy use for charging PHEVs.

- Strategy: Advanced metering will be required to enable consumers to benefit from favorable electric rate structures. Utility specifications and business models will determine meter specifications. PSC tariffs allowing rate-base recovery of additional costs specific to EV charging as opposed to unique customer cost may be helpful.

D-4 What land use issues need to be addressed?

- Strategy: Provide preferential parking, high-occupancy vehicle lanes, and lower tolls for low-carbon vehicles.

¹⁰ KEMA, *Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems*, report for ISO/RTO Council.

D-5 What kind of consumer education is needed?

- Strategy: Produce television, newspaper, and web site information for consumers similar to the current New York State Energy Research and Development Authority media campaign promoting change-out of incandescent lighting to compact fluorescent lamps.

D-6 How do we bring upfront costs down for consumers?

- Strategy: See D-2 and D-3.

D-7 What codes and standards need to be created/updated?

Vehicle charging communications has received some support from automakers because it could allow for a single industry standard for recharging mechanisms to meet the needs of the electric utility system. Automakers would prefer to see a single vehicle standard that could be universally implemented, as opposed to a patchwork of standards and technologies across state boundaries or utility service territories.

The addition of Level II charging infrastructure to an existing building can typically cost \$3,000, which can be an impediment to sales. When charging infrastructure is incorporated in new construction, the cost is \$300.

- Strategy: Develop standards that are compatible with smart-grid/smart-charging Level III and building codes that require conforming circuitry in both residential and commercial new garage construction. This will enable lower-cost market penetration and safer/more reliable service. Policy and regulations should encourage standardization of vehicle charging interfaces at the regulated utility level and with vehicle manufacturers.

E. Vehicle (End User) Strategies¹¹

E-1 What charging technologies are needed (e.g., smart charge)?

Smart charging will be needed as grid-fueled vehicle penetration grows. Shifting the vehicle charging load to off-peak time may be the biggest long-term issue. It may be necessary for public policy or rate structures to provide incentives and disincentives to implement adoption. Society of Automotive Engineers and Institute of Electrical and Electronics Engineers standards are under development, and there are several technical approaches that will enable vehicle-grid-building communication and smart charging. Energy storage technology will likely be necessary to mitigate large quantities of on-peak or fast-charging use in the future.

- Strategy: *Near term:* Encourage demonstrations of technical options, monitor performance, and explore behavioral influences of rate structures and public policy. *Long term:* Enact appropriate rate adjustments and incentives to mitigate grid problems, and conduct R&D of

¹¹ National Academy of Sciences, *Transitions to Alternative Transportation Technologies—Plug-in Hybrid Electric Vehicles*, 2009; The Electrification Coalition, *Electrification Roadmap*, 2009 (200 million EVs by 2050); CARB, *2050 Greenhouse Gas Emissions Analysis: Staff Modeling in Support of the Zero Emission Vehicle Regulation*, 2009; David L. Greene and Andreas Schafer, *Reducing Greenhouse Gas Emissions from U.S. Transportation*, prepared for Pew Center on Global Climate Change, 2003.

energy storage technologies that can utilize large quantities of excess power generated from renewable sources and baseload nuclear power (which are difficult to turn down) for on-demand and Level III quick-charge vehicle charging.

E-2 What battery technologies are most suitable for this application? Are they available and cost-effective?

Continued advances are required in battery technology and manufacturing. Significant cost reductions will be required to allow grid-charged vehicles to compete with petroleum at anything less than \$4/gallon. This may be difficult with lithium-ion technology, because of the currently low labor costs and as-of-yet undetermined sources of cheaper materials.

- Strategy: Continue R&D into the next generation of battery chemistry and explore innovative business models (battery leasing, battery change out, etc.).

E-3 What vehicle platform(s) seems the most viable? Can EVs meet driver needs, or will we need fuel cell or bio-PHEVs to meet range requirements?

The issues of vehicle range, fueling infrastructure, and cost will be challenging. Quick-charge (Level III) electric charging may require stationary storage or other upgrades. Range issues can be overcome with FCVs. However, quick fill public hydrogen infrastructure would require a major investment. Hydrogen only provides significant GHG benefits over conventional hybrids when the hydrogen is produced through electrolysis or via thermo-nuclear means. Therefore, hydrogen is a long-term option that can provide benefits if and when there is adequate (or an excess of) zero-carbon electricity. A third option, hybrid bio-PHEV, may be the easiest pathway on the vehicle side. However, low-carbon cellulosic ethanol is not a proven option.

- Strategies: None of the above options should be abandoned. All may be needed to meet the variety of duty cycles, first cost versus operating cost constraints, and user needs. In all cases, continuous improvements in vehicle technology will be needed together with significant long-term infrastructure investment. Public policy should be technology-neutral and in the near term should focus on low-carbon vehicle incentives, such as feebates for low-carbon vehicles, a low-carbon fuel standard and tax credits, and buy-downs for fueling infrastructure.

E-4 Who will service these vehicles?

- Strategies: To build the skilled workforce needed, adopt public policy and financial support for educational and workforce development programs at community colleges and the Board of Cooperative Education Services and other publicly supported schools and provide tuition assistance for these programs.

E-5 What is the rate of advanced low-carbon vehicle introduction needed to meet 80 by 50? How do we get more cars “in the pipeline”?

Over 90 percent of vehicle miles are traveled with vehicles less than 15 years old. Therefore, to achieve a near total transition to low-carbon travel by 2050, nearly all vehicles sold after 2030 would need to be low carbon.

- Strategies: Offer financial incentives for desired market transformation and disincentives for unwanted behavior to accelerate low-carbon vehicle market penetration. Fund infrastructure investments, which may require adjustments in public policy and public investment.

E-6 How do we bring upfront costs down for consumers? Are incentives required to overcome the high cost of electric vehicles?

- Strategy: Manufacturer competition may be the most cost-effective way to reduce vehicle cost, with battery manufacturing capacity and supply-demand being dominant factors. A robust market can be encouraged through incentives, adequate charging infrastructure, and education. A low-carbon fuel standard, vehicle purchase feebate, or other carbon pricing mechanism will be needed for EVs/PHEVs to be economically competitive in the near term.

Appendix H

ClimAID Report Summary

Prior to the Governor Paterson's Executive Order 24 creating the Climate Action Council the New York Energy Supply and Development Authority (NYSERDA) was undertaking research on climate change under its Environmental Monitoring, Evaluation, and Protection (EMEP) program. A key project of this program is the *Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State*, known as ClimAID.

ClimAID was undertaken to provide decision-makers with cutting-edge information on the state's vulnerability to climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge. Involving the work of scientists from universities throughout New York state and key stakeholders, the assessment identifies critical vulnerabilities, climate risks, and adaptation strategies specific to New York State, for a range of key sectors: agriculture, coastal zones, ecosystems, energy, public health, telecommunications, transportation, and water resources.

A draft summary of the ClimAid project's work, *Responding to Climate Change in New York*, is appended here in its entirety keeping its original pagination. The larger materials on which this summary is based were critical to the Council's Adaptation Technical Work Group. Several of the ClimAID report authors served on this group.

RESPONDING TO CLIMATE CHANGE IN NEW YORK STATE



New York State Energy Research and Development Authority
2010

D R A F T

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Foundation Report

NYSERDA ClimAID Team. 2010. *Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State*. C. Rosenzweig, W. Solecki, A. DeGaetano, M. O'Grady, S. Hassol, P. Grabhorn, Eds. New York State Energy Research and Development Authority (NYSERDA), 17 Columbia Circle, Albany, New York, 12203.

All the figures and tables in this document are drawn from the ClimAID Foundation Report: *Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State*.



Cornell University

Responding to Climate Change in New York State

Climate change is already beginning to affect the people and resources of New York State, and these impacts are projected to grow. At the same time, the state has the potential capacity to address many climate-related risks, thereby reducing negative impacts and taking advantage of possible opportunities.

ClimAID: the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State was undertaken to provide decision-makers with cutting-edge information on the state's vulnerability to climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge.

This state-level assessment of climate change impacts is specifically geared to assist in the development of adaptation strategies. It acknowledges the need to plan for and adapt to climate change impacts in a range of sectors: Water Resources, Coastal Zones, Ecosystems, Agriculture, Energy, Transportation, Telecommunications, and Public Health.

The author team for this report is composed of university and research scientists who are specialists in climate change science, impacts, and adaptation. To ensure that the information provided would be relevant to decisions made by public and private sector practitioners, stakeholders from state and local agencies, non-profit organizations, and the business community participated in the process as well.

This document provides a general synthesis of highlights from a larger technical report that includes much more detail, case studies, and references. The larger report provides useful information to decision-makers, such as state officials, city planners, water and energy managers, farmers, business owners, and others as they begin responding to climate change in New York State.



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CLIMATE RISKS FOR NEW YORK STATE

Temperatures are increasing, precipitation patterns are changing, and sea level is rising. These climatic changes are projected to occur at much faster than natural rates because of increased amounts of greenhouse gases in the atmosphere. Some types of extreme weather and climate events have already increased in frequency and intensity and these changes are projected to continue.

These climate changes are already having impacts in some aspects of society, the economy, and natural ecosystems and these impacts are expected to increase. Not all of these changes will be gradual. When certain tipping points are crossed, impacts can increase dramatically. Past climate is no longer a reliable guide to the future. This affects planning for water, energy, and all other social and economic systems.

Interactions

Interactions between climate change and other stresses such as pollution and increasing demand for resources will create new challenges.



Heat Waves

Heat waves will become more frequent and intense, increasing heat-related illness and death and posing new challenges to the energy system, air quality, and agriculture.



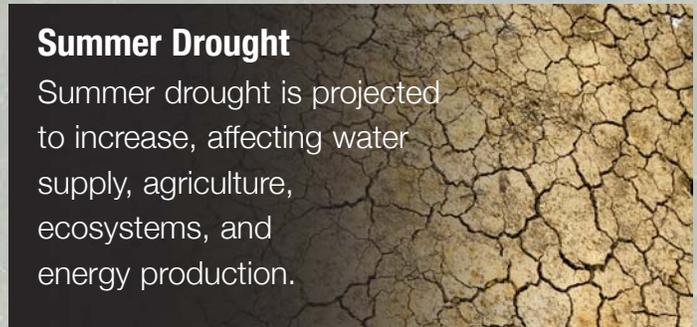
Heavy Downpours

Heavy downpours are increasing and are projected to increase further. These can lead to flooding and related impacts on water quality, infrastructure, and agriculture.



Summer Drought

Summer drought is projected to increase, affecting water supply, agriculture, ecosystems, and energy production.





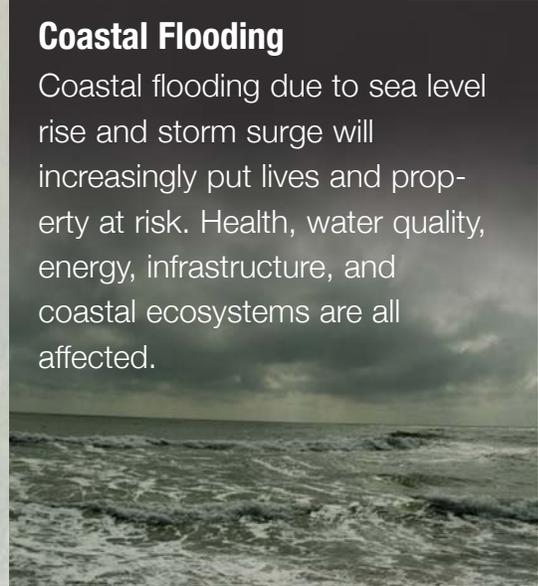
Wide Ranging Impacts

Major changes to ecosystems including species range shifts, population crashes, and other sudden transformations could have wide ranging impacts, not only for natural systems but also for health, agriculture, and other sectors.



Coastal Flooding

Coastal flooding due to sea level rise and storm surge will increasingly put lives and property at risk. Health, water quality, energy, infrastructure, and coastal ecosystems are all affected.



Opportunities

Climate change may create new opportunities related to a longer, warmer growing season for agriculture, and the potential for abundant water resources.





CLIMATE ISSUES IN NEW YORK STATE'S REGIONS

Each region of New York State (as defined by ClimAID) has unique attributes that will be affected by climate change. Many of the issues highlighted below are described in more detail in the sector discussions that follow.

Region 1: Western New York Great Lakes Plain

- Agricultural revenue highest in state
- Relatively low rainfall, increased summer drought risk
- High value crops could need irrigation
- Improved conditions for grapes projected

	Baseline	2050s	2080s
Temperature	48°F	+3.0 to 5.5°	+4.5 to 8.5°
Precipitation	37in	0 to +10%	0 to +15%

Region 3: Southern Tier

- Dairy dominates agricultural economy
- Milk production losses projected
- Susquehanna River flooding increases
- One of the first parts of the state hit by invasive insects, weeds, and other pests moving north

	Baseline	2050s	2080s
Temperature	46°F	+3.5 to 5.5°	+4.5 to 8.5°
Precipitation	38in	0 to +10%	+5 to 10%

Region 6: Tug Hill Plateau

- Important region for hydropower
- Lake effect snows could increase in the short term
- Snowmobiling opportunities decline
- Great Lakes water levels may decline

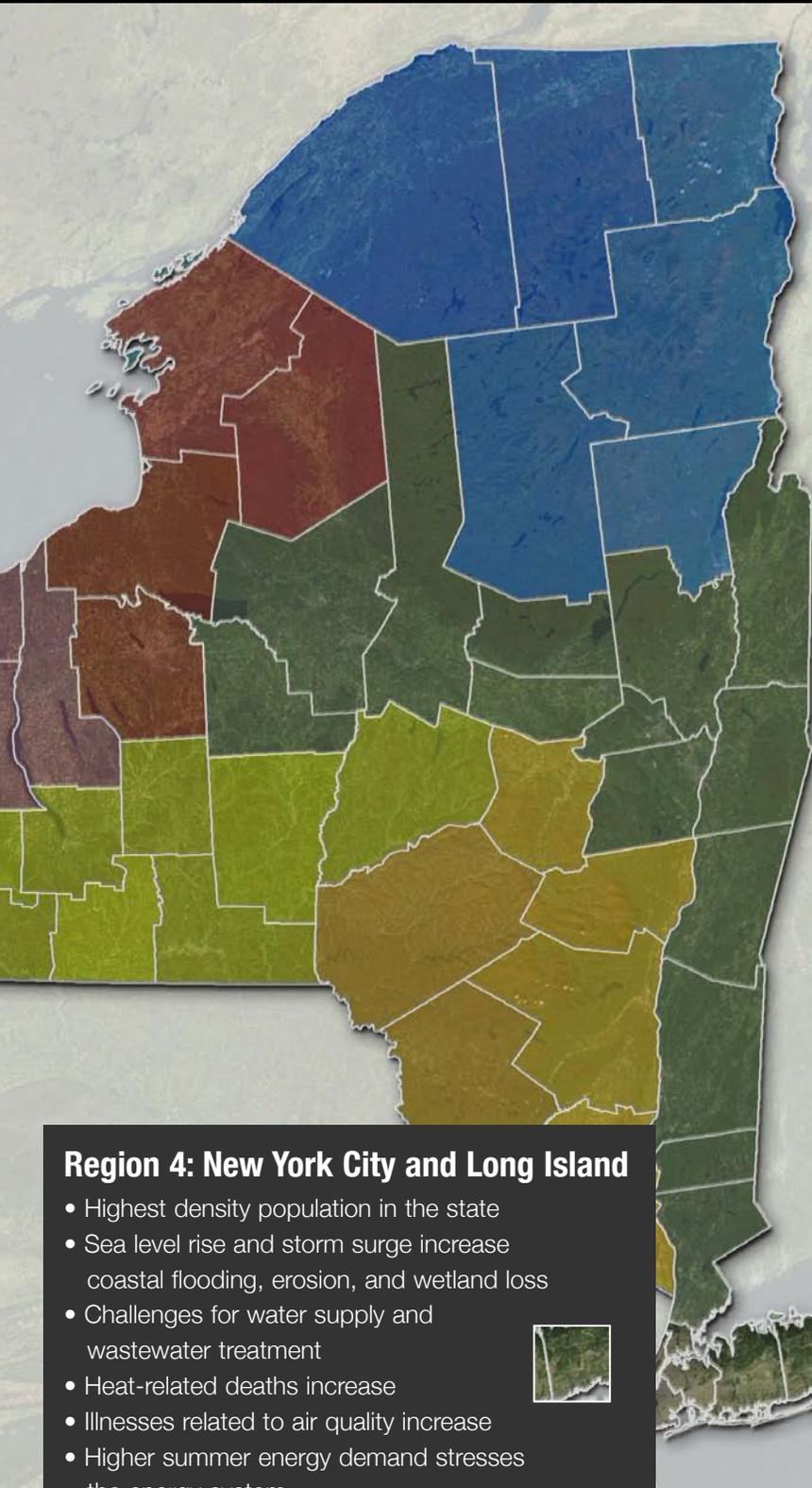
	Baseline	2050s	2080s
Temperature	44°F	+3.5 to 5.5°	+4.5 to 9.0°
Precipitation	51in	0 to +10%	+5 to 15%



Region 2: Catskill Mountains and Hudson River Valley

- Watershed for New York City water supply
- Spruce/Fir forests disappear from mountains
- Popular apple varieties decline
- Winter recreation declines; summer opportunities increase
- Hemlock wooly adelgid destroys trees
- Native brook trout decline, replaced by bass

	Baseline	2050s	2080s
Temperature	48°F	+3.0 to 5.0°	+4.0 to 8.0°
Precipitation	48in	0 to +10%	+5 to 10%



Region 7: Adirondack Mountains



- Popular tourist destination
- Loss of high-elevation plants, animals, and ecosystem types
- Winter recreation declines; summer opportunities increase
- Milk production declines, though less than other regions

	Baseline	2050s	2080s
Temperature	42°F	+3.0 to 5.5°	+4.0 to 9.0°
Precipitation	38in	0 to +5%	+5 to 15%

Region 5: Hudson and Mohawk River Valley



- Major rivers characterize this region
- Saltwater front moves further up the Hudson River
- Potential contamination of New York City's back-up water supply
- Propagation of storm surge up the Hudson from the coast
- Popular apple varieties decline

	Baseline	2050s	2080s
Temperature	50°F	+3.0 to 5.5°	+4.0 to 8.0°
Precipitation	38in	0 to +5%	+5 to 10%

Region 4: New York City and Long Island

- Highest density population in the state
- Sea level rise and storm surge increase coastal flooding, erosion, and wetland loss
- Challenges for water supply and wastewater treatment
- Heat-related deaths increase
- Illnesses related to air quality increase
- Higher summer energy demand stresses the energy system

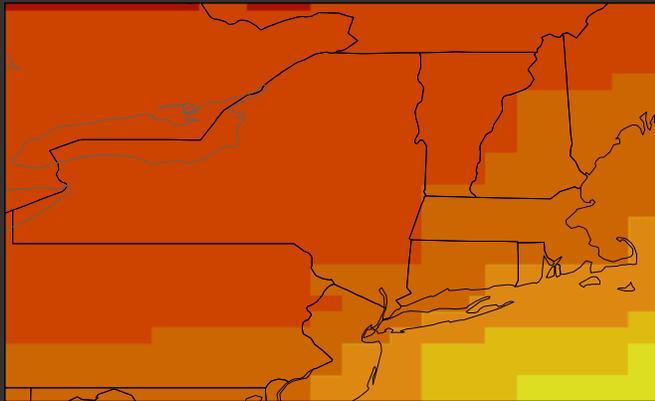


	Baseline	2050s	2080s
Temperature	53°F	+3.0 to 5.0°	+4.0 to 7.5°
Precipitation	47in	0 to +10%	+5 to 10%



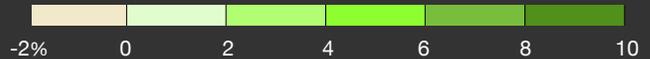
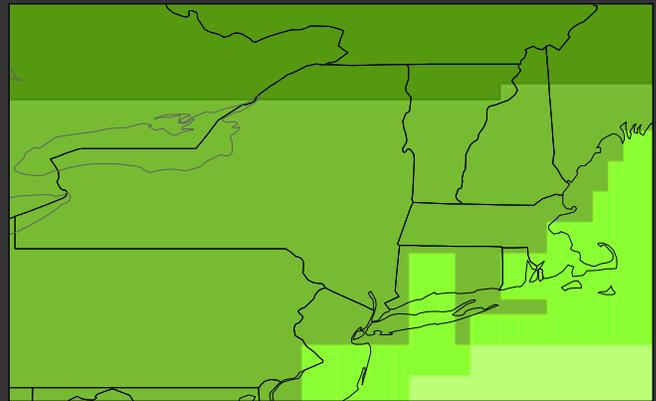
CLIMATE PROJECTIONS

Projected Annual Temperature Change - 2080s (°F)



Average annual temperatures are projected to increase by 4.0 to 9.0°F by the 2080s, with the lower end of this range projected under lower greenhouse gas emissions scenarios and the higher end under higher emissions scenarios. A mid-range emissions scenario, A1B, was used for the maps above, yielding temperature increases of about 7°F for most of the state. The A1B trajectory is associated with relatively rapid increases in emissions for the first half of this century, followed by a gradual decrease in emissions after 2050.

Projected Annual Precipitation Change - 2080s (%)



Precipitation across New York State may increase by approximately 5 to 15 percent by the 2080s, with the greatest increases in the northern parts of the state. Much of this additional precipitation may occur during the winter months as rain, while late summer and early fall precipitation could decline slightly. Both maps show the average across 16 global climate models.

Temperatures are expected to rise across the state, by 1.5 to 3°F by the 2020s, 3 to 5.5°F by the 2050s, and 4 to 9°F by the 2080s. The lower ends of these ranges are for lower greenhouse gas emissions scenarios (in which society reduces heat-trapping gas emissions) and the higher ends for higher emissions scenarios (in which emissions continue to increase). These are not the best and worst cases, however. Sharp cuts in global emissions could result in temperature increases lower than the bottoms of these ranges, while a continuation of business-as-usual could result in increases higher than the high ends.

Annual average precipitation is projected to increase by up to 5 percent by the 2020s, up to 10 percent by the 2050s and up to 15 percent by the 2080s. This will not be distributed evenly over the course of the year. Much of this additional precipitation is likely to occur during the winter months, with the possibility of slightly reduced precipitation projected for the late summer and early fall.

Continuing the observed trend, more precipitation is expected to fall in heavy downpours and less in light rains.

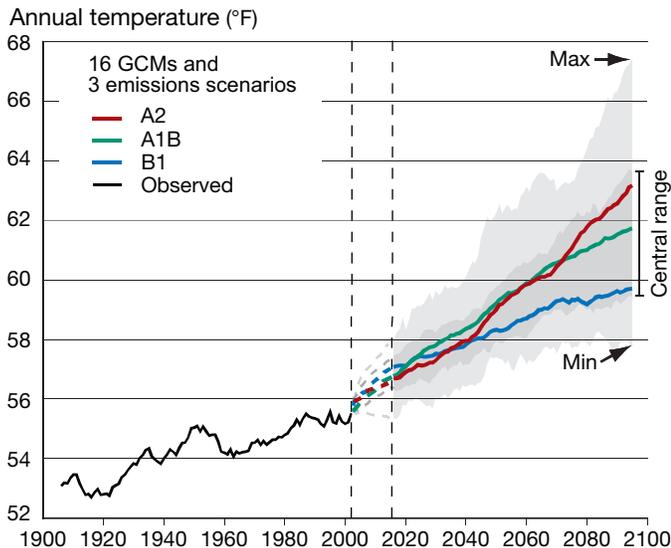
Sea level rise projections that do not include significant melting of the polar ice sheets (which is already observed to be occurring) suggest 1 to 5 inches of rise by the 2020s, 5 to 12 inches by the 2050s and 8 to 23 inches by the 2080s. Scenarios that include rapid melting of polar ice project 4 to 10 inches of sea level rise by the 2020s, 17 to 29 inches by the 2050s and 37 to 55 inches by the 2080s.

Projected Seasonal Precipitation Change - 2050s (% change)

ClimAID Region	Winter	Spring	Summer	Fall
1. Western New York Great Lakes Plain	+5 to +15	0 to +15	-10 to +10	-5 to +10
2. Catskill Mountains and Hudson River Valley	0 to +15	0 to +10	-5 to +10	-5 to +10
3. Southern Tier	+5 to +15	0 to +10	-5 to +5	-10 to +5
4. New York City and Long Island	0 to +15	0 to +10	-5 to +10	-5 to +10
5. Hudson and Mohawk River Valley	+5 to +15	-5 to +10	-5 to +5	-5 to +10
6. Tug Hill Plateau	+5 to +15	0 to +10	-5 to +10	-5 to +10
7. Adirondack Mountains	+5 to +15	-5 to +10	-5 to +5	-5 to +10



Observed and Projected Annual Temperature Change (°F)



These climate-related risks will affect the state's economy and environment. Some of the most serious vulnerabilities and potential adaptation strategies are highlighted in this report.



Higher temperatures and increased heat waves have the potential to

- increase fatigue of materials in water, energy, transportation and telecommunications infrastructure;
- affect drinking water supply;
- cause a greater frequency of summer heat stress on people, plants and animals;
- alter pest populations and habits, affecting agriculture and ecosystems;
- change the distribution of key crops such as apples, cabbage, and potatoes;
- cause reductions in dairy milk production;
- increase electricity demand for cooling;
- lead to declines in air quality that cause respiratory illness; and
- cause more heat-related deaths.



Increased frequency of heavy downpours has the potential to

- affect drinking water supply;
- heighten risk of river flooding;
- flood key rail lines, roadways and transportation hubs; and
- increase delays and hazards related to extreme weather events.



Sea level rise and coastal flooding have the potential to

- increase risk of storm surge-related flooding along coast;
- expand areas at risk of coastal flooding;
- increase vulnerability of energy facilities located in coastal areas;
- flood transportation and communication facilities; and
- cause saltwater intrusion into some freshwater supplies near the coasts.

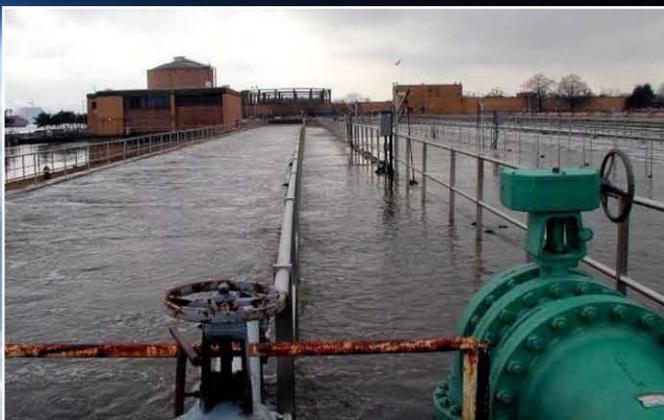
Projected Sea Level Rise for New York State (inches)

Modeled Sea Level Rise	2020s	2050s	2080s
GCM-based	+1 to +5	+5 to +12	+8 to +23
Rapid ice melt scenario	+4 to +10	+17 to +29	+37 to +55

The central range of sea level rise projections is shown, rounded to the nearest inch, based on the average of the ClimAID Global Climate Model-based (GCM) for a range of greenhouse gas emissions scenarios as reported by IPCC 2007 and the ClimAID rapid ice melt scenario (based on accelerated melting of the Greenland and West Antarctic Ice Sheets).



ADAPTATION CAN REDUCE IMPACTS



Adaptation refers to actions taken to prepare for climate change, helping to reduce adverse impacts or take advantage of beneficial ones.

Strategies can include changes in operations, management, infrastructure, and/or policies that reduce risk and/or capitalize on potential opportunities associated with climate change. Adaptations can take place at the individual, household, community, organization, and institutional level. Adaptation can be thought of as just better planning, incorporating the most current information about climate into a variety of decisions. Adaptation should be woven into the everyday practices of organizations and agencies.

Adaptive capacity refers to the ability of a system to adjust to actual or expected climate stresses or to cope with their consequences.

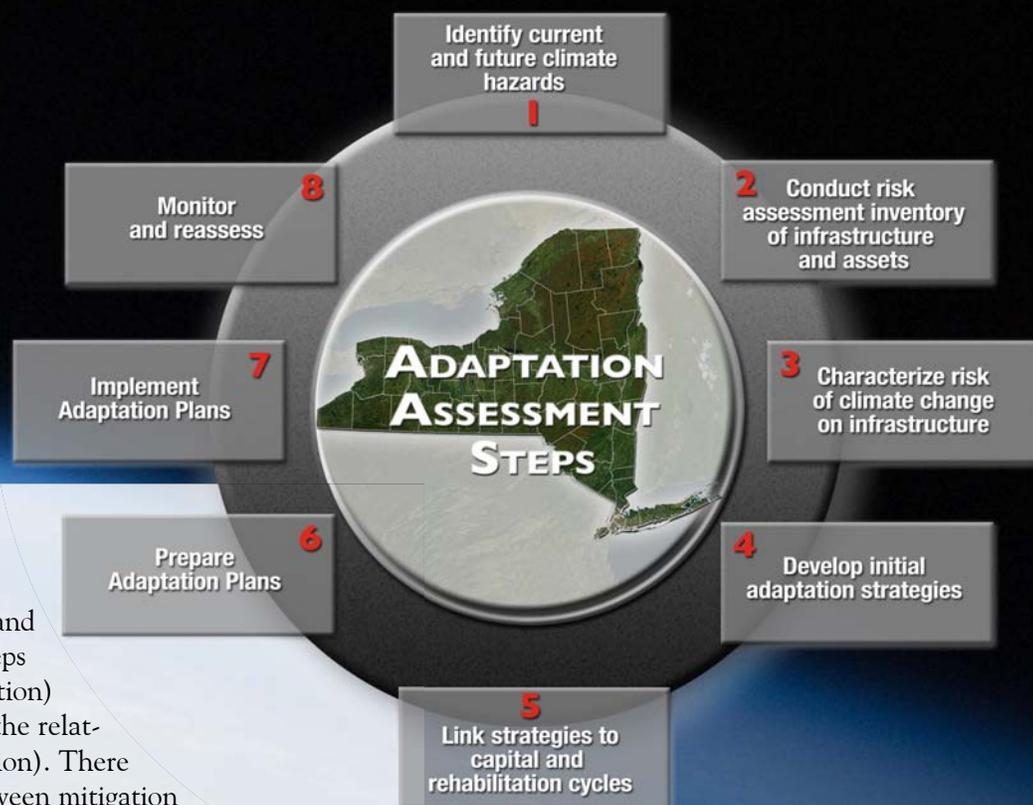
New York State as a whole is generally considered to have significant resources and capacity for effective adaptation responses. However, the costs and benefits of adaptation will not be evenly distributed throughout the state. There can also be a variety of unintended consequences of adaptation options. For example, building sea walls to protect coastal property from rising sea levels can exacerbate the loss of coastal wetlands that serve to protect coastlines from storm surge damage.

Adaptations undertaken in one sector often have implications for other sectors.

For example, increased use of air conditioning is an adaptation to reduce heat-related illness and death in the health sector as well as to reduce heat stress on livestock in the agriculture sector. However, such a strategy would increase peak summer energy use, increasing demands on both energy and water resources. If increased tree planting is used to reduce urban heat, it will be important to plant low-pollen tree species because allergenic pollen is on the rise in a warmer, higher-CO₂ world. These examples point to the need for integrated thinking about adaptation strategies to avoid creating new problems. In addition, climate change and some adaptation options can worsen social and economic inequalities that are already present and create new inequalities. This raises equity issues that are discussed on the following pages.

Adaptation strategies do not directly include actions aimed at reducing the speed and amount of climate change.

Actions to reduce climate change, often called “mitigation,” involve lowering emissions of heat-trapping gases or increasing their removal from the atmosphere. Mitigation measures would reduce climate change impacts in the longer term.



There are interactions between adaptation and mitigation.

For example, improving insulation and using reflective roofing material keeps buildings cooler in summer (adaptation) as well as reducing energy use and the related heat-trapping emissions (mitigation). There can be a variety of interactions between mitigation and adaptation measures. Some measures, such as green roofs, reduce emissions by decreasing the need for air conditioning as well as lessen impacts by keeping buildings cooler and reducing stormwater flooding. On the other hand, increasing use of air conditioning to adapt to rising temperatures results in increased emissions. Thus, mitigation and adaptation measures should be considered in concert. Both are necessary elements of an effective response strategy. These two types of responses are also linked in that more effective mitigation measures would reduce the amount of climate change, and therefore affect the need for adaptation.

Our choices can make us more or less vulnerable to climate change.

For example, building in coastal zones and river flood plains and paving over large amounts of land make us more vulnerable to flooding and inundation due to sea level rise and increasing heavy down-pours. In contrast, decisions made taking into account the adaptation principles described here can make us less vulnerable, that is, better able to withstand the impacts of climate change. However, even the best efforts to reduce vulnerability will not be sufficient to eliminate all damages associated with climate change in the long-term. The goal is to create a more climate-resilient New York State.



ADAPTATION CAN REDUCE IMPACTS



Reduce other stresses to help improve the adaptive capacity of any system, making it more resilient to climate change. This is true for water and energy supply systems, natural ecosystems, and other sectors.

- For ecosystems, options include reducing human transport of invasive species, controlling sprawl and other habitat destruction, and providing dispersal corridors to allow species range shifts in response to climate change.
- For water and energy systems, options include lowering demand through efficiency measures and consumer education.
- For coasts, reducing development and preserving wetlands through various policies can help.
- For human health, pollution reduction and better management of chronic disease would increase resilience.



Take advantage of normal capital repair and replacement cycles of infrastructure to build in climate change adaptations that are flexible to future conditions.

- When building long-lived infrastructure, such as power plants, tunnels, and bridges, consider projected increases in temperature and sea level, and changes in precipitation patterns.
- Designing a 1-foot floodwall with a strong enough foundation to support an added foot or two of height if needed is an example of flexible adaptation.
- When building new dairy barns, design for better ventilation and possibly the ability to add other cooling technologies.
- Incorporate climate change projections such as the increase in heavy downpours and sea level rise in capital investment decisions currently being made in storm water and wastewater systems.



Examine and revise regulatory mechanisms and land use policies such as zoning, setbacks, building codes, and incentives, taking climate change into account.

- Regulations concerning infrastructure such as those that govern bridge height and clearance, dam height and strength, materials used, dimensions of drainage culverts for roads, roof strength, and foundation depth should be reconsidered.
- Definitions of flood zones should be revisited and how they may change in the future should be considered.
- Regulations that affect adaptive capacity should be assessed. For example, stronger regulations to control invasive species can help make ecosystems more resilient, and stronger efficiency standards can make water and energy systems more resilient.
- Changes in treaties such as those governing water rights might be appropriate if the amounts and distributions of the resources change. Risk sharing mechanisms including various types of insurance and regional planning approaches should also be examined.



Improve monitoring, measurement, and data gathering and distribution to provide the information needed to adapt as climate change proceeds.

- Monitor climate change science for the latest developments.
- A central repository for information on new norms for climate, species, etc. would help to reduce uncertainty and better inform policy.
- Monitoring the effectiveness of various adaptation strategies is important.
- There is a need to better monitor hazards and events, and to archive and make this information widely available. This might include air quality monitoring, citizen watches for invasive species, and real-time data gathering on the impacts of extreme weather events (such as, crop and timber value lost, reduction in dairy production, cost of property damaged, and numbers of heat-related illnesses and deaths).
- In addition to monitoring hazards, events, and adaptation strategies, combine the tracking of these indicators to improve understanding of what impacts will result from various climate events and what adaptation strategies are effective.



ENVIRONMENTAL EQUITY

Climate change risks, vulnerabilities, and capacities to adapt are uneven across regions, sectors, households, individuals, and social groups.

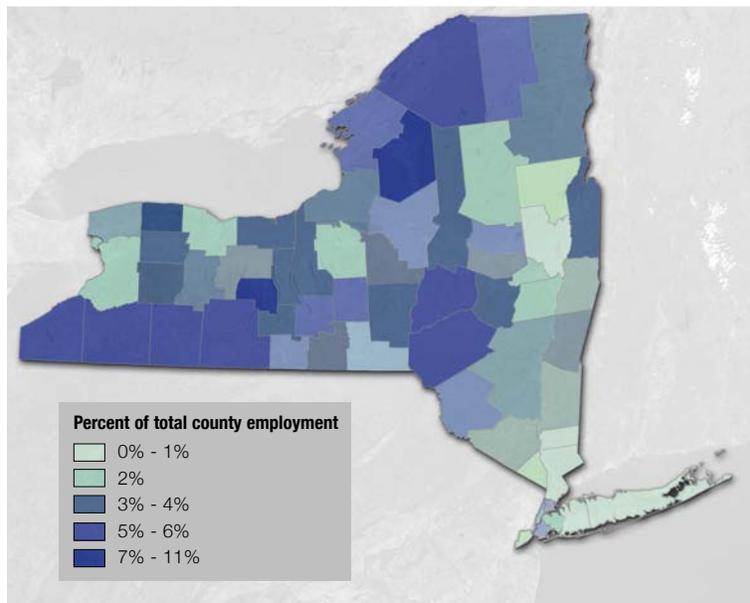
Certain groups will be disproportionately affected by the impacts of climate change.

Equity issues emerge because climate change impacts and adaptation policies can worsen existing inequalities and can also create new patterns of winners and losers.

Intergenerational equity issues arise from the fact that future generations will suffer the consequences of past and current generations' actions.

The same groups, such as the elderly, tend to be at risk for adverse impacts of climate change across multiple sectors.

Employment in Agriculture, Forestry, Fishing and Related Activities



Areas/Locations

- Rural areas, especially small towns, are more vulnerable to, and have less capacity to

cope with, extreme events such as floods, droughts, ice storms and other climate-related stressors.

- Regions that depend on agriculture and tourism (such as fishing, skiing, and snowmobiling) may be especially in need of adaptation assistance.
- Low-income urban neighborhoods, especially those within flood zones, are less able to cope with climate impacts such as heat waves, flooding, and coastal storms.
- Coastal zones are vulnerable to sea level rise and storm surge. There are already numerous properties in coastal zones that cannot get insurance, for example.



Groups

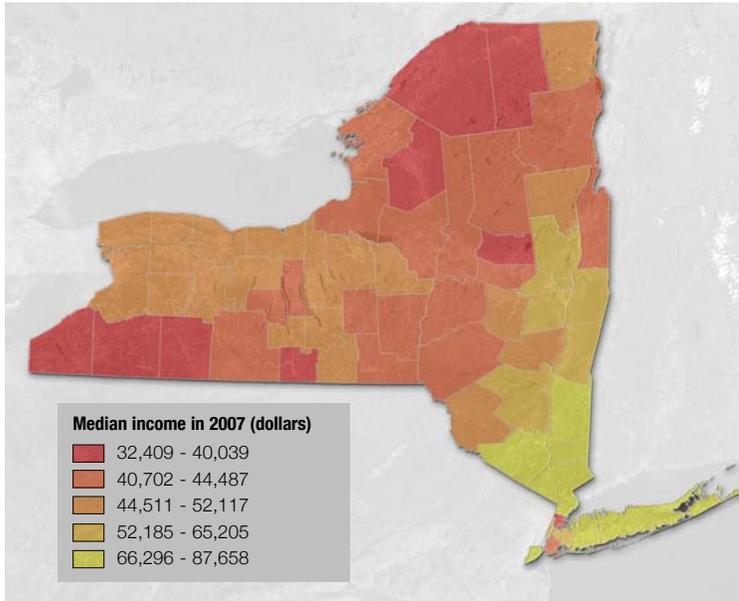
- Elderly, disabled and health-compromised individuals are more vulnerable to climate

hazards, including floods and heat waves.

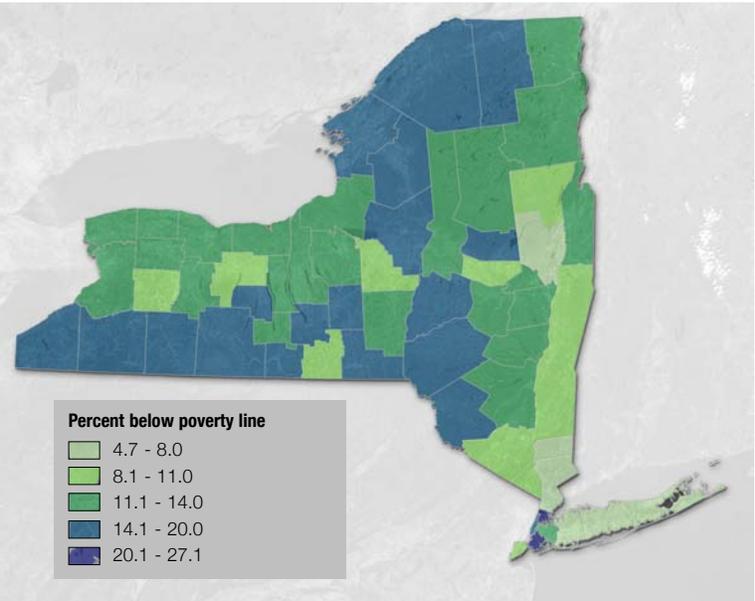
- Low-income groups have limited ability to meet higher energy costs, making them more vulnerable to the effects of heat waves.
- Those who lack affordable health care are more vulnerable to climate-related illnesses such as asthma.
- Those who depend on public transportation to get to work, and lack private cars for evacuating during emergencies, are vulnerable.
- Farm workers may be exposed to more chemicals if pesticide use increases in response to climate change.
- Asthma sufferers will be more vulnerable to the decline in air quality during heat waves.



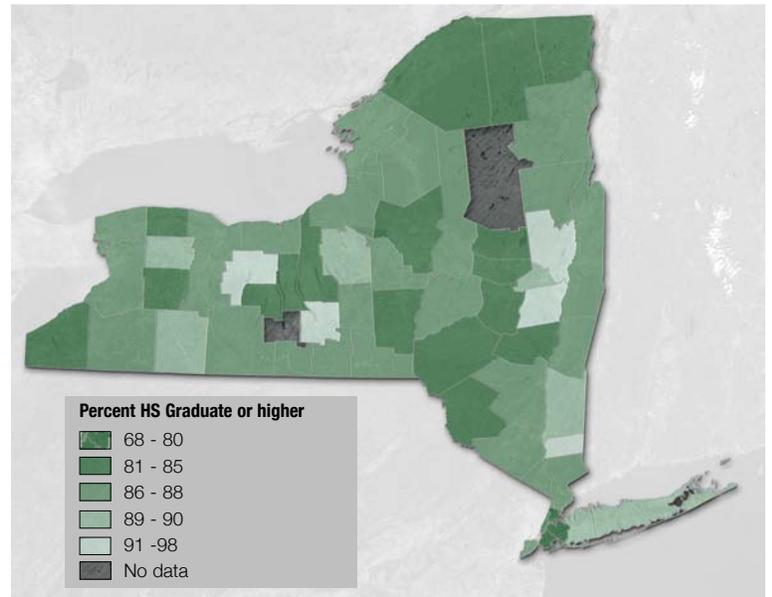
Income Disparities



Poverty Rates



Educational Attainment



Firms and Industries



- Smaller businesses are less able to cope with climate-related interruptions and stresses than larger businesses.
- With often more limited capital reserves, smaller firms are less able to withstand revenue loss associated with power and communication service disruptions.
- Small businesses tend to have less capital available to make investments to promote adaptation, such as the use of snowmaking in ski areas, or adoption of new crops or techniques on small farms.

There is a need for more attention to how the impacts of climate change adaptation policies affect different populations, areas, and industries. Affected communities and populations should have a voice in the adaptation policy process.



ECONOMICS



New York State's climate has already begun to change and impacts related to increasing temperatures and sea level rise are already being felt in the state, with associated costs. Future climate change has the potential to cause even more significant economic costs for New York State. Additional economic costs are likely to be tens of billions of dollars per year by the middle of this century. However, many costs of climate change are still not known and are difficult to estimate. Climate-change related economic impacts will be experienced in all sectors, types of communities and regions across the state.

Types of Climate Impact Costs

Direct costs include costs that are incurred as the direct economic outcomes of a specific climate event or aspect of climate change. Direct costs can be measured by standard methods of national income accounting, including lost production and loss of value to consumers.

Indirect costs are costs incurred as secondary outcomes of the direct costs of a specific event or facet of climate change. Examples include jobs lost in firms that provide inputs to firms directly harmed by climate change.

Impact costs are direct costs associated with the impacts of climate change, for example the reduction in milk produced by dairy cows due to heat stress.

Adaptation costs include direct costs associated with adapting to the impacts of climate change, such as the cost of cooling dairy barns to reduce heat stress on dairy cows.

Costs of residual damage are direct costs of impacts that cannot be adapted to, for example, reductions in milk production due to heat stress that may occur if cooling capacity is exceeded.

Regions

All regions of the state will incur economic costs associated with climate change. Specific economic impacts will affect particular regions. For example, the negative impact on the state's winter recreation industry will adversely affect the Catskill and Adirondack regions.

The coastal zone, because of its relative exposure and vulnerability to storms and the concentration of residences, businesses, and infrastructure on the shore, will experience the greatest economic impact of any single region. The urbanized areas of the state with high population density will incur higher public health costs because of existing and projected urban heat island conditions.

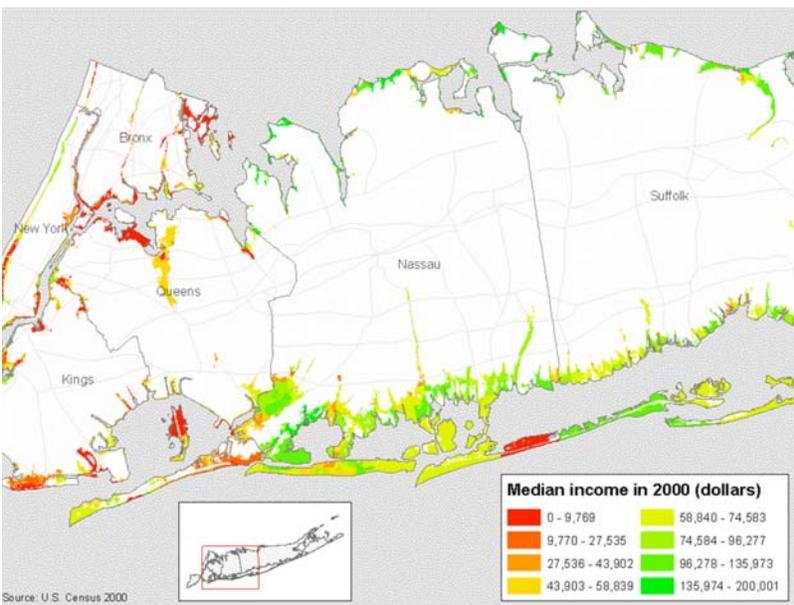
Sectors

All sectors will incur costs associated with climate change; however, the costs will be highly uneven across and within sectors.

- All sectors are likely to experience significant economic impacts that may alter the overall structure and function of the sector.
- Water and flooding related management costs will affect almost all sectors.
- The highest direct economic costs of climate change are connected to large scale capital investment, housing, and commercial activity in the coastal zone.
- Sectors such as agriculture and telecommunications are inherently dynamic, changing annually, seasonally, and in some cases even daily. The economic consequences of climate change will be woven into the risk management and operations of the sector.



Economic Diversity of Coastal Populations



New York City and Long Island are among the areas most at risk from climate change. The areas in color on this map are already at risk from coastal flooding during storms, and much more land will be at risk as sea level rise accelerates. The impacts and costs of climate change and adaptation options in this heavily developed coastal zone will be large and diverse. There is a great deal of property in harm's way, including long-lived, high-value infrastructure such as roads, airports, bridges, and power plants. As shown on the map, the population of this region is very diverse, from low income inner-city neighborhoods to very high income communities.

Timing

Economic costs of climate change impacts will generally increase throughout the century as the rate of climate change accelerates. Some of the largest costs will be associated with extreme events such as large scale floods and heat waves. Costs associated with average climate changes are expected to increase more slowly over time.

The timing of impacts could be more mixed for sectors that are expected to experience both potential benefits and costs. For example, in the agricultural sector, short term costs could eventually be overwhelmed by the emergence of longer term benefits, or vice versa.



Climate Change Adaptation Costs and Benefits

The implementation of adaptation strategies will bring economic benefits to the state. For each sector, a wide variety of adaptation options at varying costs are available.

- Transportation, the coastal zone, and water resources will have the most significant climate change impact costs and will require the most adaptations.
- Energy, telecommunications, and agriculture sectors have costs that could be large if there is no adaptation; but adaptation to climate could be seen as a regular part of moderate re-investment.
- The benefit-cost ratio comparing avoided impacts to costs of adaptation is highest for the public health and coastal zones sectors, moderate for the water resources, agriculture, energy, and transportation sectors, and low for the telecommunications sector.



Context

New York State has an abundance of water resources, including large freshwater lakes, high-yielding groundwater aquifers and major rivers.

Water resources are managed by a diverse array of large and small agencies, governments and institutions, with little statewide coordination.

Water resources are already subject to numerous human-induced stresses, such as increasing demand for water and insufficient water supply coordination; these pressures are likely to increase over the next several decades.

Water quality is already at risk from aging wastewater treatment plants, continued combined sewage overflow events, and excess pollution from agricultural and urban areas.

Key Climate Impacts

Rising air temperatures intensify the water cycle by driving increased evaporation and precipitation. The resulting altered patterns of precipitation include more rain falling in heavy events, often with longer dry periods in between. Such changes can have a variety of effects on water resources.



Heavy downpours have increased over the past 50 years and this trend is projected to continue, causing an increase in localized flash flooding in urban areas and hilly regions.



Flooding has the potential to increase pollutants in the water supply and inundate wastewater treatment plants and other vulnerable development within floodplains.



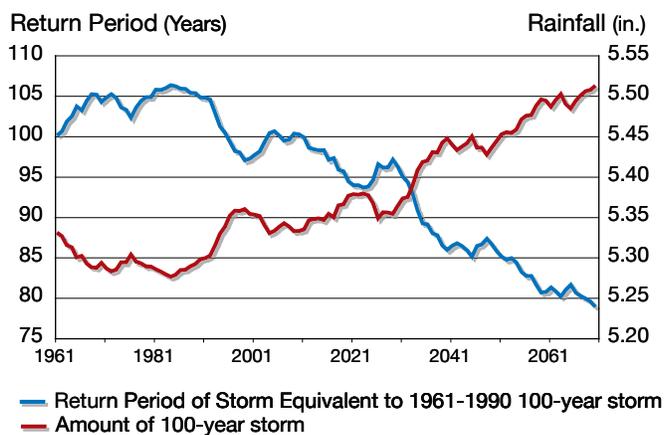
Less frequent summer rainfall is expected to result in additional, and possibly longer, summer dry periods, potentially impacting the ability of water supply systems to meet demands.



Reduced summer flows on large rivers and lowered groundwater tables could lead to conflicts among competing water users.

Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent from wastewater treatment plants.

Projected rainfall and frequency of extreme storms



The amount of rain falling in a "100-year" storm is projected to increase (red line), while the number of years between such storms ("return period") is projected to decrease (blue line). Thus, rainstorms will become both more severe and more frequent. These results, from the UK Met Office Hadley Centre Climate Model Version 3 (HadCM3), are broadly consistent with those of the other 15 GCMs used by ClimAID.



Adaptation Options

Adaptation can build on water managers' existing capacity to handle large variability. Strategies can be designed to be flexible to a range of future conditions. New York's relative wealth of water resources, if properly managed, can contribute to resilience and new economic opportunities.

Operations, Management, and Infrastructure Strategies

- Relocate infrastructure such as wastewater treatment plants and high-density housing to higher elevations and outside of high risk floodplains. For infrastructure that must remain in the floodplain, elevate structures, construct berms or levees to reduce flood damage.
- Adopt stormwater infrastructure and management practices and upgrade combined sewer and stormwater systems to reduce pollution.

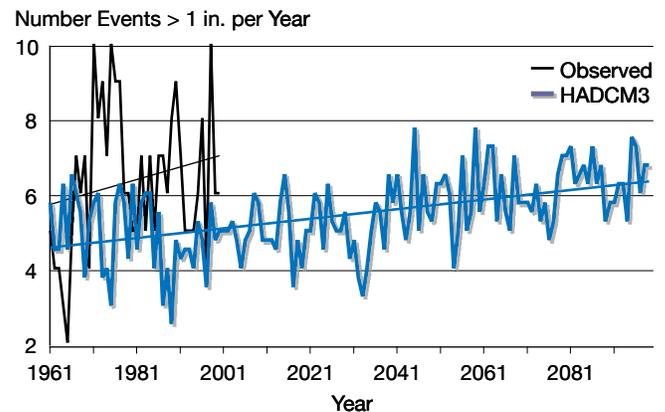
Larger-scale Strategies

- Use multiple strategies to increase water use efficiency. Conserve water through leak detection programs; use of low-flow showerheads, toilets, and washing machines; and rain barrels for garden watering. Research equitable water pricing programs.
- Establish stream flow regulations that mimic natural seasonal flow patterns, including minimum flow requirements, to protect aquatic ecosystem health.
- Expand basin-level commissions to provide better oversight, address water quality issues, and take leadership on monitoring, conservation, coordination of emergency response, and new infrastructure.
- Develop more comprehensive drought management programs that include improved monitoring of water supply storage levels and that institute specific conservation measures when supplies decline below set thresholds. Update and enlarge stockpiles of emergency equipment to help small water supply systems and to assist during emergencies.

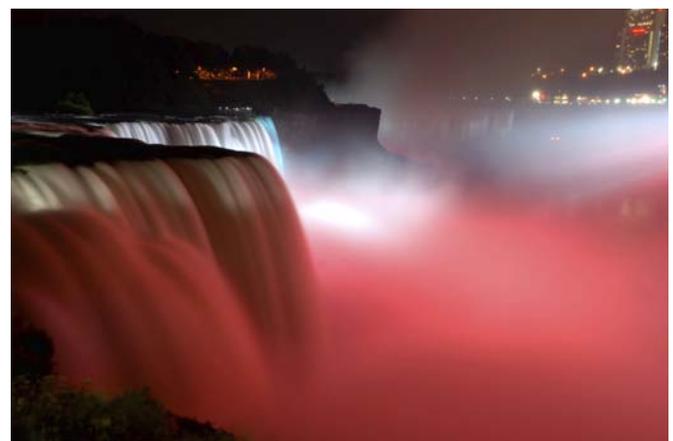
Co-Benefits

Continuing and expanding current water resource management practices, such as reducing stormwater runoff into water bodies, will benefit pollution control as well as climate adaptation. Encouraging water conservation strategies and minimum flow criteria to prepare for potential summer droughts will help to guarantee water sufficiency.

The number of rainfall events over one inch from 1960-2100



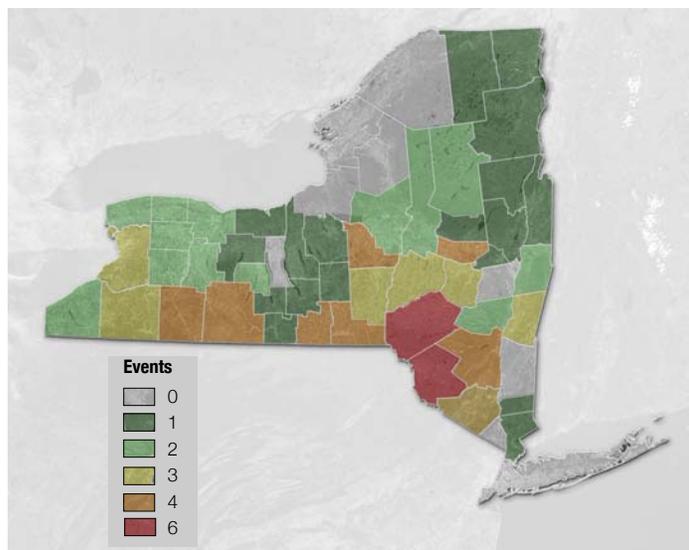
The observed number of rainfall events exceeding one inch from 1960 to 2000 is shown by the black line, and the projected number of such events, using the HadCM3 model, is shown by blue line. These results are broadly consistent with those of the other 15 GCMs used by ClimAID.





WATER RESOURCES

Flood Events Per County from 1994-2006



Number of FEMA-declared flood disasters in New York state counties. (FEMA)

Particularly Vulnerable Groups

Smaller water systems are more vulnerable to drought and other types of water supply disruptions than larger systems, since large systems tend to be more closely managed and often have more resources for dealing with drought.

The elderly and people with disabilities tend to be more vulnerable to immediate flood hazards due to limited mobility.

Rapidly developing, higher-income exurban communities may experience water scarcity as demand increases in these areas and overwhelms local supplies.

Lower-income or non-English speaking populations may be particularly vulnerable to increasing levels of disease-causing agents in the water supply or contaminants in well water as they may be less aware of government programs and warnings and have less access to health care.

Susquehanna River Flooding, June 2006

The value of preparedness

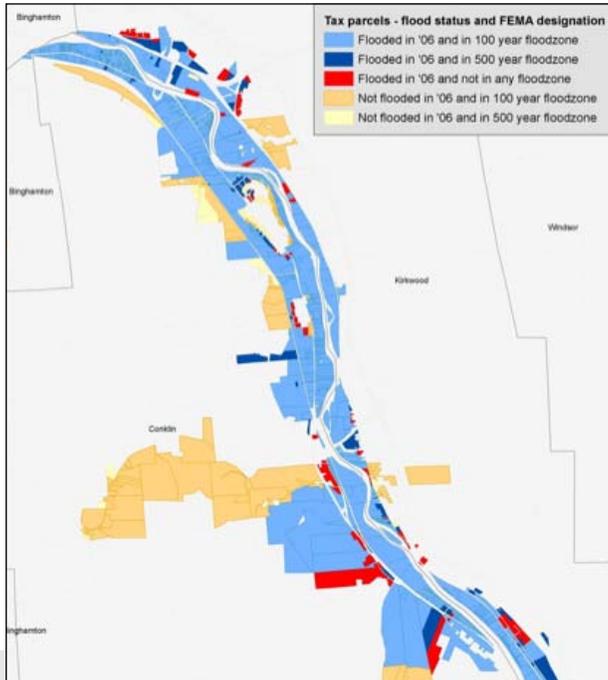
Flooding is already a major problem across New York State with damages costing an average of \$50 million each year. There are several flood management strategies that can help solve current problems while addressing possible future ones.

The June 2006 Susquehanna River flood-the largest on record since gauging began on the river in 1912-provides insights into strategies that can be used to reduce flood risks and impacts. Record precipitation from June 25 to 28, totaling 3 to 11 inches, culminated in significant flooding in the basin. Twelve counties in New York and 30 in Pennsylvania were declared disaster areas. Rainfall coupled with runoff from steep hillsides contributed to river water levels rising from less than 5 feet to nearly 21 feet in nine hours. Broome County, N.Y., incurred the most damages.

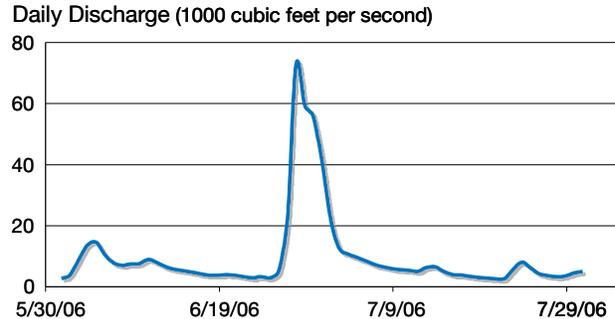
In Broome County, about 3,350 properties were flooded. Fifty-eight percent of the flooded properties were residential and 10 percent were commercial. Nearly 30 percent of the shopping area, two sewage treatment plants, a public works facility, a hospital, and several hundred miles of roads were also flooded. The town of Conklin was the hardest hit, with 30 percent of its properties flooded, followed by 13 percent in Kirkwood, and 10 percent in Port Dickinson. In total, 1,020 of the properties that were flooded were not within FEMA's Special Flood Hazard Area, including 723 residential properties. These properties were valued at more than \$46.3 million and were exempt from having federally mandated insurance.



**Distribution of flood risks in a select area in Broome County
Properties flooded in 2006 relative to FEMA floodzone designation**



**Water level of the Susquehanna River at Conklin, N.Y.
during the June 2006 flood.**



Days of very heavy rain on top of already saturated soils from weeks of rain, caused a huge spike in the level of the Susquehanna River (chart above), flooding thousands of properties, including Lourdes Hospital (photo below).



Despite the very rapid onset of the flood and the thousands of properties that were inundated, there were only four deaths, thanks to the Susquehanna River Basin's well-developed flood-response system. The area has an excellent warning-and-response system that links NOAA-based weather forecasts to real-time USGS streamflow data and coordinates with regional and local emergency response teams. The June 2006 response included pre-flood community-wide warnings and evacuations, water pumping and sand bag efforts, and emergency evacuations and medical services during the flood. Such a system is not inexpensive to operate; a single USGS gauge can cost nearly \$20,000 per year to maintain and the system has nearly 10 such gauges. However, the value of such an early warning system is apparent when large floods do occur, and remains important for the future.

While the area has extensive levees and dams, some are outdated and the current system is not adequate to deal with potential higher-magnitude floods. Development within the floodplains behind these barriers has intensified, making communities more vulnerable and damages greater when floods occur. Strategies to help further reduce flood risk include moving out of the highest risk areas with homeowner buyouts following floods, and relocating infrastructure, such as wastewater treatment plants, out of floodplains. This strategy was used successfully in Conklin, and elsewhere. It reduces subsequent flood risk, both to lives and buildings, and monetary costs can be comparable to or less than costs to expand levees. It also expands natural flood-control processes by expanding the undeveloped areas so that floodwaters can spread out and dissipate instead of being forced downstream. In some areas, downstream flooding can also be lessened by reducing stormwater runoff through improving soil infiltration capacity, expanding vegetated surfaces, and decreasing impervious surfaces such as roads.



COASTAL ZONES



Key Climate Impacts

High water levels, strong winds, and heavy precipitation resulting from strong coastal storms already cause billions of dollars in damages and disrupt transportation and power distribution systems. Sea level rise will lead to more frequent and extensive coastal flooding. Warming ocean waters raise sea level through thermal expansion and have the potential to strengthen the most powerful storms.



Barrier islands are being dramatically altered by strong coastal storms as ocean waters overwash dunes, create new inlets, and erode beaches.



Sea level rise will greatly amplify risks to coastal populations and will lead to permanent inundation of low-lying areas, more frequent flooding by storm surges, and increased beach erosion.



Loss of coastal wetlands reduces species diversity, including fish and shellfish populations.

Some marine species, such as lobsters, are moving north out of New York State, while other species, such as the blue claw crab, are increasing in the warmer waters.



Saltwater could reach farther up the Hudson River and in estuaries, contaminating water supplies. Tides and storm surges may propagate farther, increasing flood risk both near and far from the coast.



Sea level rise may become the dominant stressor acting on vulnerable salt marshes.

Context

New York's coastal zones are becoming more developed, further increasing the consequences of flooding, coastal erosion, and sea level rise.

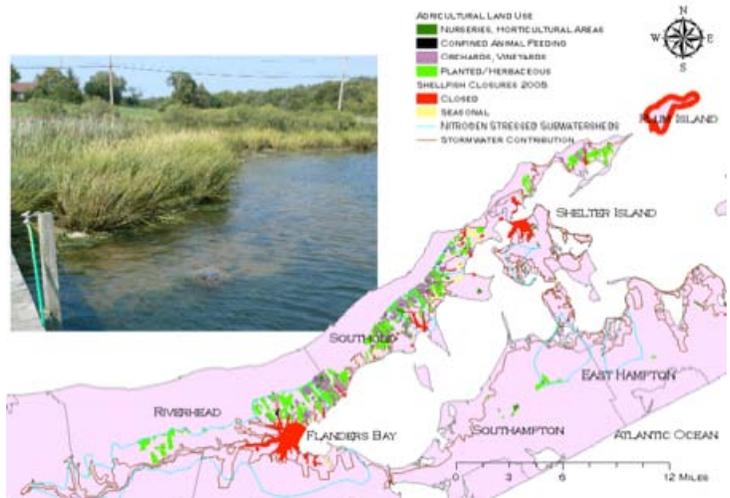
More than a half million people live within the 100-year coastal floodplain in New York State.

Coastal marshes and wetlands are highly sensitive and must maintain a delicate balance as they are affected by rapid sea level rise, wave erosion, sediment deposition and other forces. These important ecosystems provide wildlife habitat, protect coastlines against storms, and absorb pollution.

Coastal impacts propagate into inland areas, such as up the Hudson River, all the way to the Troy Dam.

Closures of Shellfish Harvesting Related to Agricultural Practices

The impacts of climate change occur in the context of numerous other stresses, many of which are also caused by human activities. While climate change increases air and water temperatures and alters precipitation and runoff patterns, nitrogen from agricultural areas is an additional stress that harms fish and shellfish in the coastal zone. The map shows shellfish closures for the Peconic River Estuary in 2005 and the agricultural land use practices that contribute to such closures.





New York's highly developed and populated coastlines are vulnerable to severe coastal storms, such as hurricanes.

Adaptation Options

Implementation of adaptation strategies in coastal zones is complicated by the complex interactions of natural and human systems and competing demands for resources.

Operations, Management, and Infrastructure Strategies

- Move sand onto beaches, although doing so can lead to habitat disruption and erosion in the area of removal, and is only a temporary solution. Add sediment from shipping channels to marshes, although this may not keep up with the rate of loss.
- Consider use of engineering-based strategies such as constructing or raising sea walls, and bio-engineered strategies including restoring or creating wetlands.
- Site new infrastructure and developments outside of future floodplains, taking into consideration the effects of sea level rise, erosion of barrier islands and coastlines, and wetland inundation.

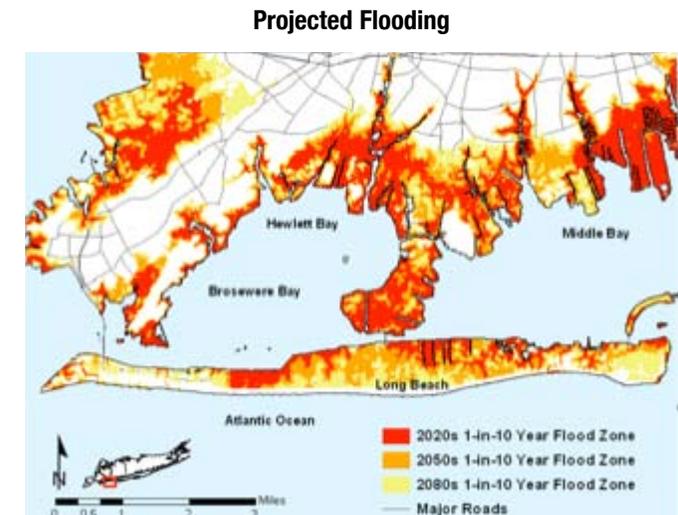
Larger-scale Strategies

- Buy out land or perform land swaps to encourage people to move out of flood-prone areas and allow for wetlands to shift inland. Enact rolling easements to help protect coastal wetlands by prohibiting seawall construction while still allowing some near-shore development.
- Improve building codes to promote storm-resistant structures and increase shoreline setbacks.

Particularly Vulnerable Groups

Within the coastal zone, elderly and disabled residents and households without cars are particularly vulnerable to flood hazards as they have more difficulty evacuating in a timely manner.

Low-income populations living in coastal and near-coastal zones will be less able to recover from damages resulting from extreme weather events than will wealthier populations.



Projected flood map for 1-in-10 year storm event for Long Beach and surrounding bay communities for ClimAID rapid ice melt scenario.

Co-benefits

Protecting wetland areas has mitigation and other ecosystem service co-benefits because they provide critical functions such as capturing carbon, providing habitat for fish and other species, and serving as a buffer for storm surge.

Racial and ethnic minorities are more vulnerable to extreme events than nonminority populations; African Americans and Latinos represent a significant portion of the people living in the New York City flood zone.

Coldwater marine species, such as lobsters, are vulnerable to increases in sea surface temperature and some are already beginning to move north out of New York State waters.

Freshwater ecosystems in estuaries are vulnerable to saltwater intrusion as sea level rises.



COASTAL ZONES



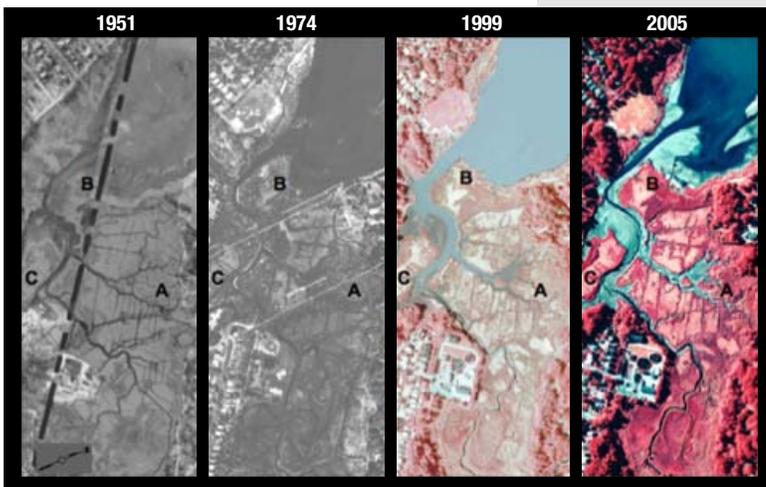
Effects of sea level rise on vital coastal wetlands

Salt marshes are essential ecosystems in New York State that provide a number of services including protection against coastal storm damage, habitat for migratory birds, nurseries for local fisheries, and recreation opportunities for residents. Over the past several decades, the area of these essential ecosystems has declined dramatically.

While sea level rise is currently a relatively minor component among several human-induced stressors (including draining of marshes, building seawalls, and dredging navigation channels) that may be contributing to the submergence and loss of vulnerable marshes, sea level rise may become the dominant factor in future decades.

At Jamaica Bay in New York City, island salt marsh area declined by 20 to 35 percent between the mid-1920s and mid-1970s. Since the mid 1970s, despite the implementation of regulations limiting dredging and filling activity, the rate of loss has accelerated; by 2008 close to 70 percent of the mid-1920s marsh area had been lost. In a 2003 pilot project at Big Egg Marsh, sediment was sprayed to a thickness of up to 3 feet and plugs of *Spartina alterniflora*, a marsh plant, were planted. In 2006 at Elder's Point East, a large-scale, \$12 million restoration project used sand from maintenance dredging to artificially elevate the marsh. At both sites, the elevated stands of marsh plants are currently thriving. The successes of these two projects led to initiation of the 2010 restoration at Elder's Point West with plans underway for Yellow Bar Hassock.

Salt Marsh Loss Comparisons



Udalls Cove Park Preserve, Queens, NY

Udalls Cove Park in Queens and Pelham Bay Park in the Bronx have also experienced significant marsh loss. At Udalls Cove Park, marsh area has declined by 38 percent since 1974 and by 33 and 45 percent at two locations in Pelham Bay Park. Monitoring stations have been established in these parks to track the changes. The data are being used in combination with projected rates of sea level rise and aerial photographs to assist park managers, scientists and public advocates in managing and thereby perhaps minimizing salt marsh loss in the coming decades.



Sea level rise and severe coastal storms

Vulnerability of urban and suburban communities

New York's highly developed and populated coastlines are vulnerable to severe coastal storms, such as hurricanes. The urban and suburban regions of Long Beach and the communities along the mainland coastline of Great South Bay are two examples of areas at risk. Flood adaptation strategies for such areas require a holistic approach that promotes resiliency across communities.

Sea level rise in combination with a coastal storm that currently occurs about once every 100 years on average is expected to place a growing population and more property at risk from flood and storm damage. In 2020, nearly 96,000 people in the Long Beach area alone may be at risk from sea level rise under the rapid ice melt scenario; by 2080, that number may rise to more than 114,500 people. The value of property at risk in the Long Beach area under this scenario ranges from about \$6.4 billion in 2020 to about \$7.2 billion in 2080.

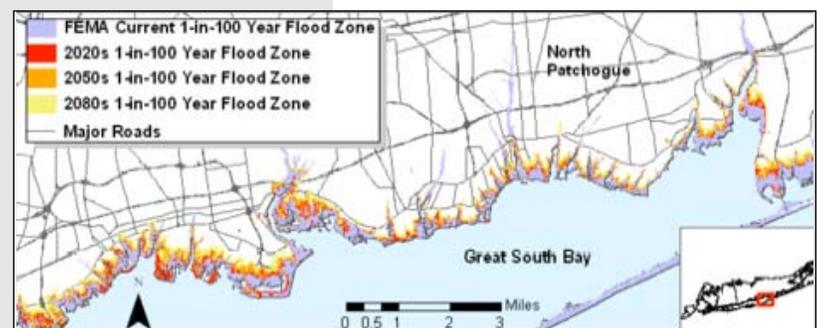
To help protect against the effects of sea level rise and coastal storm flooding, a number of adaptation strategies could be undertaken. In terms of financial cost, relocating agricultural and low-density residential development further away from the coast is an appropriate adaptation strategy. Engineering-based strategies, such as constructing levees and sea walls, can be appropriate for moderate- and high-density development, although they involve tradeoffs.

Each adaptation measure may create new patterns of winners and losers. For example, sea walls may protect some people within a community while others are left vulnerable to flooding. Seawalls also prevent wetlands from migrating inland, resulting in the loss of wetlands that are important nurseries for marine species and that also help protect the coastline from damage during storms. Relocating infrastructure to higher elevation areas may result in gentrification in the upland community, making low-income populations more vulnerable. Such patterns of vulnerability need to be considered when planning for adaptation to reduce climate change impacts.

Sea level rise will lead to more frequent and extensive coastal flooding.



Flood Zone for a 1-in-100 Year Storm in Great South Bay



The map shows areas projected to be flooded in three future time periods based on projections from 7 global climate models, 3 emissions scenarios, and the rapid ice melt scenario used in ClimAID.



Context

The vast majority of New York's forests and other natural landscapes are privately owned (more than 90 percent of the state's 15.8 million acres of potential timberland), with implications for land-use planning and policies.

Urbanization and other land-use changes have fragmented large, connected habitats important for species dispersal and migration.

Increasing deer populations cause economic losses to agricultural crops and urban landscapes, and their selective feeding in natural landscapes alters plant community structure with cascading effects on other species.

Many non-climate stressors currently have negative effects on New York's ecosystems. These stressors include invasive species, air pollution, acid precipitation, and excess nitrogen and phosphorus in the state's waterways.

Key Climate Impacts

Within the next several decades New York State is likely to see widespread shifts in species composition in the state's forests and other natural landscapes, with the loss of spruce-fir forests, alpine tundra and boreal plant communities.

Climate change will favor the expansion of some invasive species into New York, such as the aggressive weed, kudzu, and the insect pest, hemlock woolly adelgid. Some habitat and food generalists (such as white-tailed deer) may also benefit.

A longer growing season and the potential fertilization effect of increasing carbon dioxide could increase the productivity of some hardwood tree species, provided growth is not limited by other factors such as drought or nutrient deficiency.

Carbon dioxide fertilization tends to preferentially increase the growth rate of fast growing species, which are often weeds and other invasive species.

Lakes, streams, inland wetlands and associated aquatic species will be highly vulnerable to changes in the timing, supply, and intensity of rainfall and snowmelt, groundwater recharge and duration of ice cover.

Increasing water temperatures will negatively affect brook trout and other native coldwater fish.





Adaptation Options

When considering adaptation strategies for ecosystems, it is important to manage primarily for important ecosystem services and biodiversity rather than attempting to maintain the current mix of species.

Operations, Management, and Infrastructure Strategies

- Develop management interventions to reduce vulnerability of high-priority species and communities, and determine minimum area needed to maintain boreal or other threatened ecosystems.

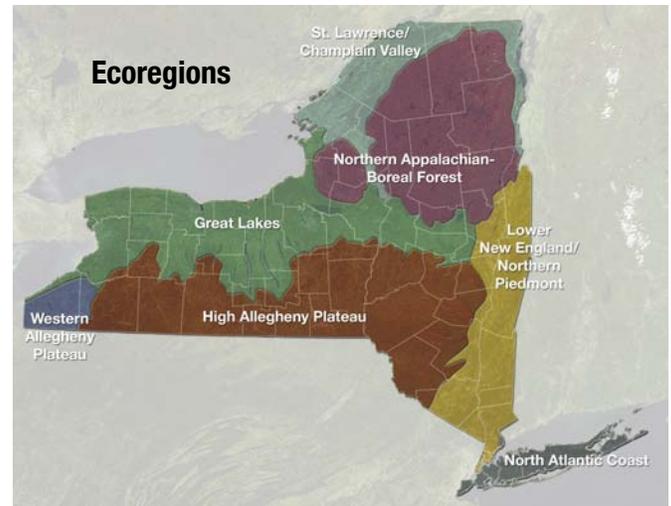
Larger-scale Strategies

- Maintain healthy ecosystems so they are more tolerant or better able to adapt to climate change by minimizing other stressors such as pollution, invasive species, and sprawl and other habitat-destroying forces.
- Facilitate natural adaptation by protecting riparian zones and migration corridors for species adjusting to climate changes.
- Institutionalize a comprehensive and coordinated monitoring effort and accessible database to track species range shifts and other indicators of habitat and ecosystem response to climate change. Identifying and prioritizing what to monitor and, in some cases, developing new indicators will be required.

Co-benefits

Maintaining healthy ecosystems in a changing climate will allow them to continue to provide services such as provision of water resources, maintenance of biodiversity, and recreation.

New York's state fish, the brook trout, is at particular risk from hemlock loss and is already at risk from increasing temperatures.



Ecosystem Services

Healthy ecosystems are our life support system, providing us with essential goods and services that would be extremely expensive or impossible to replace. Ecosystems purify air and water, and provide flood control. They supply us with products like food and timber, and sequester carbon and build soils. They provide recreation, hunting, and fishing, and wild places in which to enjoy nature. Human disruption of ecosystems, through climate change and other factors such as habitat destruction and pollution, can reduce ecosystems' ability to provide us with these valuable services.

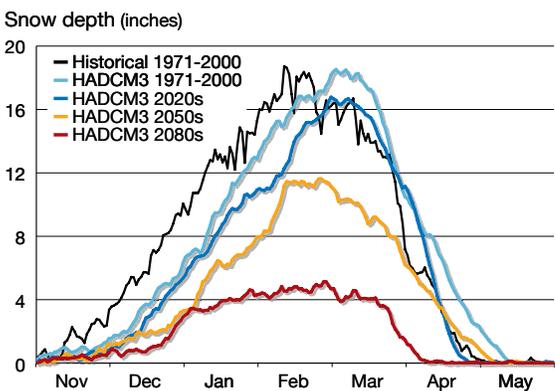




ECOSYSTEMS



Seasonal Snow Depth at Wanakena, N.Y. (Adirondacks)



Snowpack is projected to decline sharply due to future warming. The black line shows historical snowpack, and the colored lines show projected snowpack over the months with snow for three future time periods under one relatively high emissions scenario (A2) using one global climate model, UK Met Office Hadley Centre Model version 3 (HadCM3). These projections are broadly consistent with those of other models used in ClimAID.

Particularly Vulnerable Groups

Communities whose economies depend on skiing and snowmobiling will be negatively affected by higher temperatures and reduced snowpack.

Communities that depend on tourism associated with coldwater fisheries such as trout could be particularly vulnerable, although there could be increases in warmer water fish species that could help offset these losses.

Characteristics that make species and communities highly vulnerable to climate change include: being adapted to cold or high-elevation conditions; being near the southern boundary of their ranges; having a narrow range of temperature tolerance; having specialized habitat or food requirements; being susceptible to new competitors, invasive species, or pests; having poor dispersal ability; having low genetic diversity; and having low population levels.

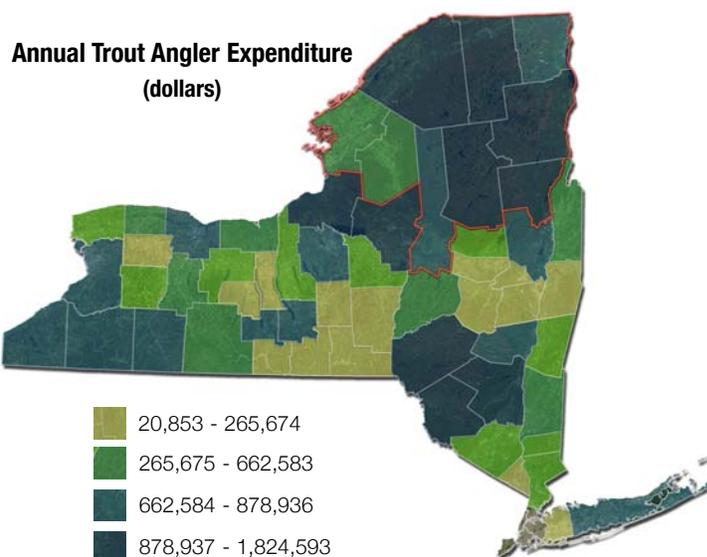
Vulnerable species and ecosystems include: spruce-fir forests of the Adirondack and Catskill mountains; boreal and alpine tundra communities of the Adirondack mountains; hemlock forests; brook trout, Atlantic salmon, and other coldwater fish; snow-dependent species such as snowshoe hare, voles and other rodents, and their winter predators such as fox and bobcat; moose; bird species such as Baltimore oriole and rose-breasted grosbeak; amphibians and other wetland species.



Bobcat



Snowshoe Hare

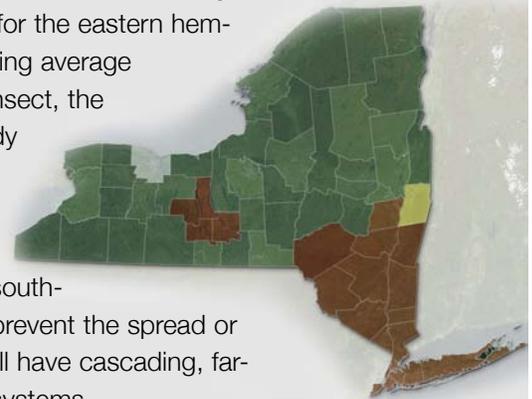




Cascading effects of climate change on animals, plants, and the economy

Shaded and cool hemlock forests provide unique wildlife habitat and are the single most prevalent conifer species in New York state. Suitable habitat for the eastern hemlock is expected to decline in New York as a result of increasing average summer temperatures as well as the spread of the invasive insect, the hemlock woolly adelgid. The hemlock woolly adelgid is already well established in New York and recently has spread to the central part of the state, in part due to rising winter temperatures that are allowing the insect to survive the winter.

Hemlocks already are dying from infestations in New York's southern and Hudson Valley regions. Currently there is no way to prevent the spread or the effects of the insect. Extensive loss of hemlock forests will have cascading, far-reaching effects on a variety of wildlife species and their ecosystems.



■ Infested Counties
■ Eastern Hemlock Range
■ Newly Infested (2009)

New York's state fish, the brook trout, is at particular risk from hemlock loss and is already at risk from increasing temperatures. The southern extent of the habitable range for brook trout is in New York and the historical abundance of the fish is likely to be severely reduced by warming. Brook trout depend on coldwater refuges in streams and lakes to survive. Lakes that are unstratified lack coldwater refuges and are likely to lose all of their trout. These represent about 41 percent of brook trout lakes in the Adirondack Mountains, for example. Brook trout in streams and rivers will also be vulnerable as water temperatures rise along with air temperatures. Their vulnerability will be complicated by the extensive loss of hemlock forests, which shade and maintain lower water temperatures in streams.

The loss of brook trout will cause changes in New York's fishing economy and may have disproportionate effects on small, fishing-dependent communities in which millions of dollars are spent by tourists who come to fish for trout. Possible adaptation strategies for keeping streams cool enough for brook trout include maintaining or increasing vegetation that provides shade along rivers, streams, and lake shorelines, and minimizing disturbances that would impede water flows and groundwater inputs.

Even more important from an economic perspective are the broader impacts of climate change on mountain forests. The local economies of the Adirondacks, Catskills, and Finger Lakes are dominated by tourism and recreation. Two-thirds of the current tree species in mountainous areas of the Adirondacks will be outside of their sustainable climate zone and in severe decline by the end of this century if current emissions trends continue.

Hunting, fishing and wildlife viewing make significant contributions to New York State's economy. More than 4.6 million people fish, hunt, or wildlife watch in the state, spending \$3.5 billion annually on equipment, trip-related expenditures, licenses, contributions, land ownership and leasing and other items. The loss of spruce-fir forests and alpine meadows will negatively affect these experiences and their economic contributions to the state.

Winter recreation is another major component of the economic value of the state's natural ecosystems. New York has more ski areas than any other state, hosting an average of 4 million visitors each year, contributing \$1 billion to the state's economy and employing 10,000 people. New York is also part of a six-state network of snowmobile trails that totals 40,500 miles and contributes \$3 billion each year to the Northeast regional economy. Shorter, warmer winters and reduced snowpack will have significant negative impacts on winter recreation in the state and the region.



AGRICULTURE



Key Climate Impacts

Increased summer heat stress will negatively affect cool-season crops and livestock unless farmers take adaptive measures such as shifting to more heat-tolerant crop varieties and improving cooling capacity of livestock facilities.



Increased weed and pest pressure associated with longer growing seasons and warmer winters will be an increasingly important challenge.



Water management will be a more serious challenge for New York farmers in the future due to increased frequency of heavy rainfall events, and more frequent and intense summer water deficits by mid to late century.



Opportunities to explore new crops, new varieties, and new markets will come with higher temperatures and a longer growing season.

Context

The agriculture sector in New York State encompasses more than 34,000 farms that occupy about one-quarter of the state's land area (more than 7.5 million acres) and contribute \$4.5 billion annually to the state's economy.

A large majority of New York agriculture is currently rain-fed without irrigation, but summer precipitation is currently not sufficient to fully meet crop water needs most years.

Economic pressures have led to consolidation into fewer, larger farms, particularly in the dairy industry. The costs of adapting to climate change may exacerbate this trend.

Agriculture is sensitive to the volatile and rising costs of energy, a challenge that climate change is likely to exacerbate.



Early season produce can provide a large fraction of a farmer's income. Heavy downpours can delay spring planting and/or damage crops, greatly reducing this important source of revenue.



Adaptation Options

A changing climate presents challenges and potential opportunities for New York state farmers. Responding will necessitate both on-farm and state-level strategies.

Operations, Management, and Infrastructure Strategies

- Change planting dates, varieties or crops grown. Increase farm diversification.
- Improve cooling capacity, including the use of fans and sprinklers in dairy barns.
- Increase use of chemical and non-chemical techniques for controlling pests, pathogens, and weeds.
- Develop new crop varieties for projected New York climate and market opportunities.
- Invest in irrigation and/or drainage systems.

Larger-scale Strategies

- Develop decision tools to assist farmers in determining the optimum timing and magnitude of investments to cope with climate change.

Co-benefits

There are several opportunities for reducing greenhouse gas emissions with agriculture adaptation options including improved manure management, generation of on-site energy, increasing the use of soil organic matter, and using nitrogen fertilizer more efficiently.



Changes for the grape industry

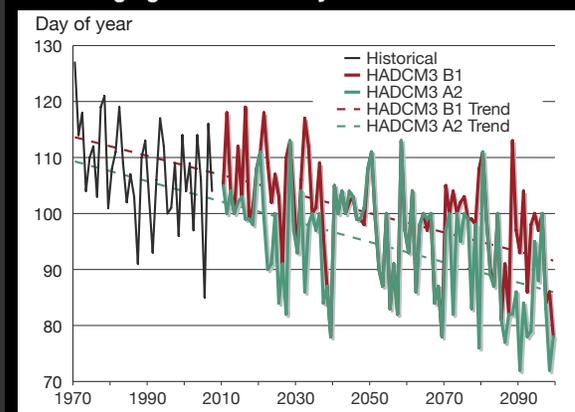
New York's grape harvest ranked third in the nation in 2007, with the crop valued at nearly 50 million dollars. In recent years, however, challenges associated with cold injury to crops have cost the states agriculture industry millions of dollars. Increasing temperatures at the beginning of winter reduce cold hardiness and can raise the probability of midwinter damage. In late winter or early spring (after the winter-chilling requirement has been met), an earlier arrival of spring or a prolonged warm period may lead to premature budding and increased vulnerability to spring frost. Projections indicate a slight increase in the potential for spring frost injury in Concord grapes.

In the long term, warmer winters and a longer growing season may bring opportunities to introduce a wider range of high value, less cold-tolerant European red wine grape varieties such as Cabernet Sauvignon and Zinfandel, that currently are constrained by the state's climate.

Adaptation strategies to avoid damage from spring frost events (such as using wind machines that pull warmer air down from high above ground during temperature inversions, and changing pruning and mulching strategies) are well established. New research will be required to integrate weather forecasts into early-warning systems for extreme events such as hard freeze and spring frost events. Linking these warning systems to the susceptibility of crops to damage could help reduce losses.



Changing Date of the Day of Last Frost



As climate warms, the date of last frost comes ever earlier in the year. The chart shows the date of last frost as the number of days after January 1. The black line shows observations. The red line shows a model projection (HadCM3) based on a lower emissions scenario (B1) while the green line shows that model's projection based on a higher emissions scenario (A2). Higher emissions mean more warming and hence cause the last frost day to occur even earlier in the year. This model's projections are broadly consistent with those of the other models used in ClimAID.



Particularly Vulnerable Groups

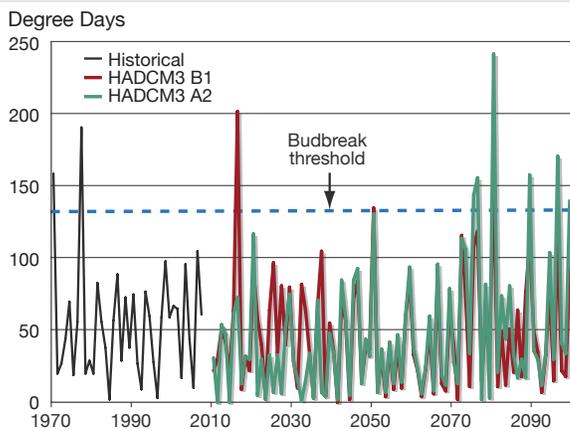
Dairy milk production and the productivity and/or quality of some cool-season crops such as apples, potatoes, and cabbage will be particularly vulnerable to increases in summer heat stress. Adaptations such as improving cooling capacity of dairy barns or changing varieties or crops are straightforward but will not be cost-free or risk-free. For example, the state could lose some favorite varieties of apples, such as McIntosh and Empire, for which it currently has national recognition, and have to replace them with more heat-tolerant varieties.

Smaller farms may have less information and training and less capital to invest in adaptation strategies such as stress-tolerant plant varieties, increased chemical and water inputs, and enhanced livestock cooling. By adding to already severe competitive pressure, climate change is likely to exacerbate current trends towards consolidation into fewer, larger farms, especially in the dairy sector.

Farms specializing in cool-season crops may have challenges finding appropriate new varieties that meet both production demands and market expectations.

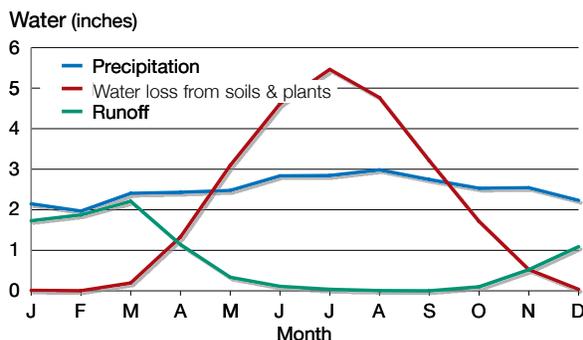
Without pro-active development of non-chemical approaches, increased pesticide and fertilizer use could harm sensitive environments, such as streams and rivers.

Projected Degree Days above 60°F Prior to Last Frost



As temperatures rise, plants flower earlier in the spring. This can make them more vulnerable to damage from late spring frost. Climate change has the potential to exacerbate this vulnerability in Concord grapes grown in New York state. The dotted blue line represents a cumulative degree-day threshold that would lead to bud break prior to the last spring frost for Concord grapes in the Fredonia region. Years exceeding the threshold would have a high risk of frost damage. As the chart shows, under a higher emissions scenarios (A2, green line), this is projected happen much more frequently in the later part of this century. These results are broadly consistent with the other global climate models used in ClimAID.

Seasonal Differences in Soil-Water Balance



The chart shows historical averages for each month of the year for precipitation, evaporative water loss from soils and plants, and runoff. Runoff is the fraction of precipitation that is not evaporated and exceeds the soil-holding capacity and thus passes into deep groundwater or into streams. The red line shows that there is a moisture deficit in summertime as evaporative losses increase due to higher temperatures, resulting in virtually no runoff during the warmest months. ClimAID projections show that both the summer deficit and winter excess are expected to increase in a warming climate.



Dairy Heat Stress

Heat stress has both short- and long-term effects on the health and performance of dairy cattle depending on severity and timing of the stress. Short-term impacts include decreases in feed intake and milk production. Under heat stress cows spend less time resting and more time standing and walking. A decrease of 1 hour of resting time is associated with a decrease of 2 to 3 pounds of milk produced per cow. Severe heat stress can cause lameness and poor reproductive performance (calving), with subsequent long-term negative effects on milk production. While short-term responses can be partially reversed after a heat wave, long-term effects are less easily reversed.

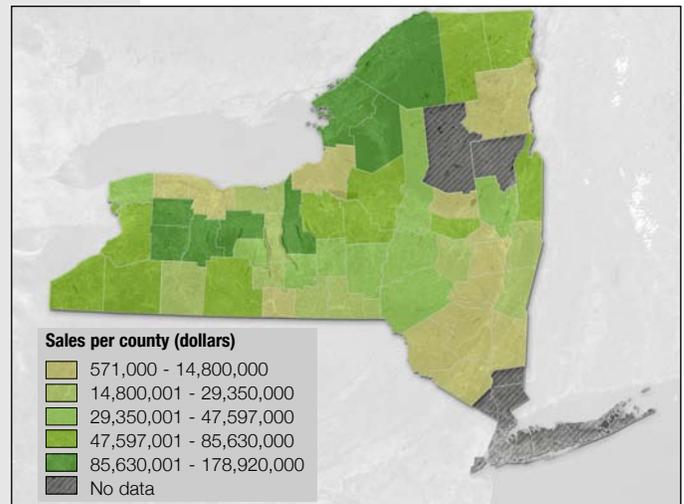


By the 2080s, the magnitude of annual N.Y. milk production decline associated with heat stress is projected to increase six-fold compared to current heat stress-related declines.

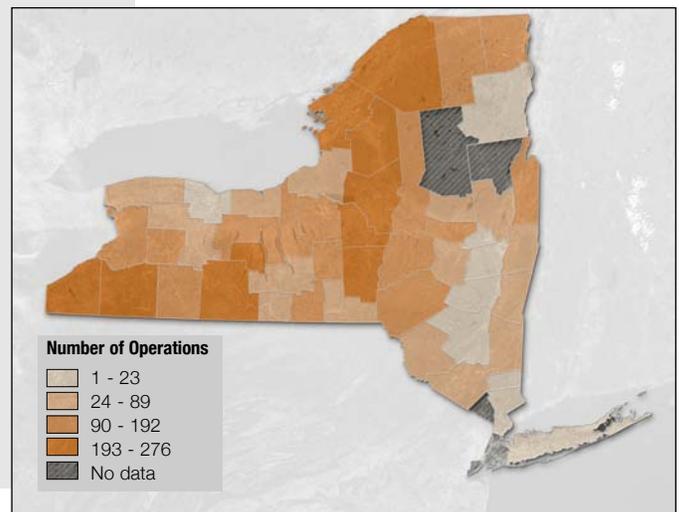
By the 2080s, the magnitude of annual N.Y. milk production decline associated with heat stress is projected to increase six-fold compared to current heat stress-related declines. Economic losses associated with the projected increase in heat stress range from \$37 to \$66 per cow per year. These ClimAID estimates took into account only short-term heat stress effects. They did not consider the potential long-term effects of severe stress on milk production, so they may underestimate losses.

Modifying feeding and providing adequate water can help ameliorate heat stress in cows, but cannot substitute for improving cooling capacity in dairy barns (for example, through improved ventilation, high airspeeds directly over the cows, and sprinkler systems). Many ventilation systems are inherently more cost-effective when deployed for larger barns. Small farms that cannot afford these kinds of adaptation measures will be most vulnerable to the impacts of warming.

Variations in Dairy Sales



Distribution of Dairy Operations





Context

The energy system in New York State is designed to cope with a wide range of climate variability.

Climate change is likely to exacerbate existing risks rather than create new ones.

Extreme, short-term weather events and changes in demand are particularly important to the energy industry.

The state's annual electricity load has increased by about 4.3 percent per year. New York City and Long Island account for about half of the total demand.

New York State's electricity sources vary regionally. For example, about half the fossil fuel-fired plants are in New York City and Long Island while most of the state's hydropower is in central and northern New York.

Wind power deployment is expected to increase across the state.

Natural gas is the most commonly used source of heating energy in buildings, although there are strong regional differences, which reflect the lack of gas service in many parts of the state.

Energy prices vary widely, with higher prices in eastern New York than in western parts of the state.

Key Climate Impacts

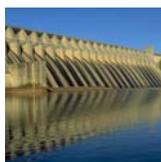
Impacts of climate change on energy demand are likely to be more significant than impacts on supply. Climate change will adversely affect system operations, increase the difficulty of ensuring adequate supply during peak demand periods, and exacerbate problematic conditions, such as the urban heat island effect.



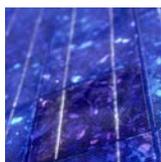
More frequent heat waves will cause an increase in the use of air conditioning, stressing power supplies and increasing peak demand loads.



Increased air and water temperatures will decrease the efficiency of power plants, as they decrease cooling capacity.



Coastal infrastructure is vulnerable to flooding as a result of sea level rise and coastal storms.



Hydropower is vulnerable to projected increases in summer drought.

The availability and reliability of solar power systems are vulnerable to changes in cloud cover although this may be offset by advances in technology; wind power systems are similarly vulnerable to changes in wind speed and direction.



Biomass energy availability depends on weather conditions during the growing season, which will be affected by a changing climate.



Transformers and distribution lines for both electric and gas supply are vulnerable to extreme weather events, such as heat waves and flooding.

Higher winter temperatures are expected to decrease winter heating demand, which will primarily affect natural gas markets, while increases in cooling demand will affect electricity markets; such changes will vary regionally.



The indirect financial impacts of climate change may be greater than the direct impacts of climate change. These indirect impacts include those to investors and insurance companies as infrastructure becomes more vulnerable and those borne by consumers due to changing energy prices and the need to use more energy.



Adaptation Options

Planning for climate change must balance the need to make energy systems more resilient with the cost of such investments and changes. One way to do this is to incorporate adaptation planning into the replacement cycles of system assets, which have a long but relatively fixed lifespan. As temperatures rise, it will be even more important to encourage the use of energy efficient cooling methods such as shading buildings and windows, or using highly reflective roof paints to reduce buildings' temperatures. Although demand-side management, which encourages consumers to use energy more efficiently, is already a key state policy, it could be made an even greater priority.

Operations, Management, and Infrastructure Strategies

- Use transformers and wiring that function efficiently at higher temperatures.
- Construct berms and levees to protect infrastructure from flooding; install saltwater-resistant transformers to protect against sea level rise and saltwater intrusion.
- Review and revise tree trimming practices to account for changes in vegetation due to climate change.

Larger-scale Strategies

- Adjust reservoir release policies to ensure sufficient summer hydropower capacity.
- Improve energy efficiency in areas that are likely to have the largest increases in demand.

Co-benefits

Increasing energy efficiency can help people to adapt to higher temperatures while reducing greenhouse gas emissions in order to mitigate climate change.

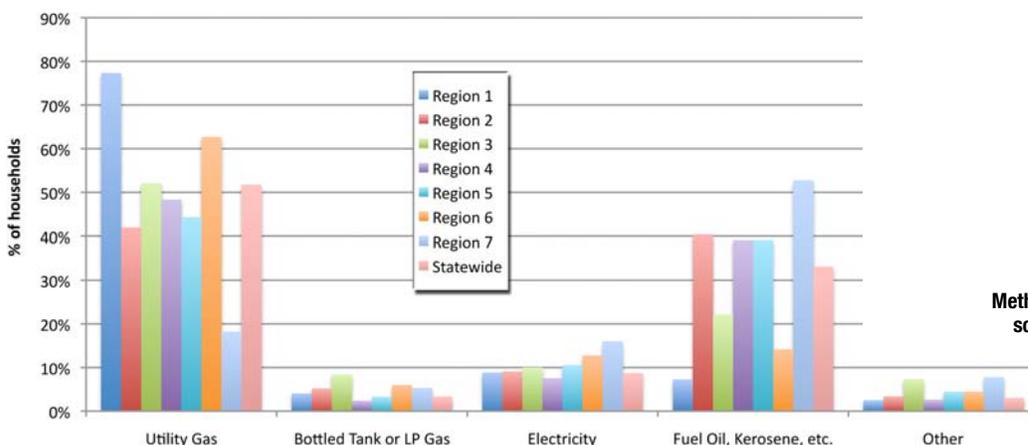


Projected changes in peak electricity demand for heating and cooling - 2020s (compared to current peak demand)

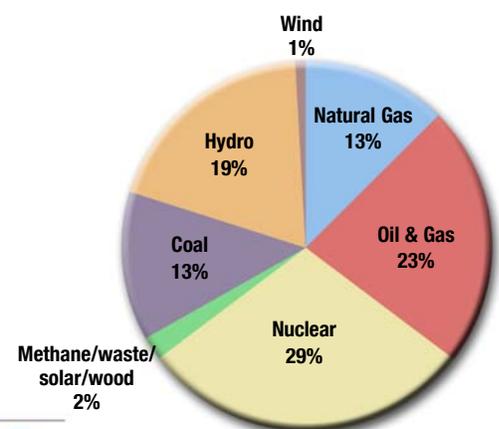
Weather Station	Heating Season Decrease in MWp Electricity Demand in 2020s	Cooling Season Increase in MWp Electricity Demand in 2020s
Buffalo	14 - 27	55 - 111
Rochester	9 - 18	53 - 105
Syracuse	19 - 37	61 - 122
Massena	5 - 10	7 - 15
Watertown	11 - 21	29 - 57
Albany	15 - 29	63 - 126
Poughkeepsie	12 - 25	72 - 145
NY City (LGA)	40 - 80	249 - 497
Islip	27 - 58	194 - 387

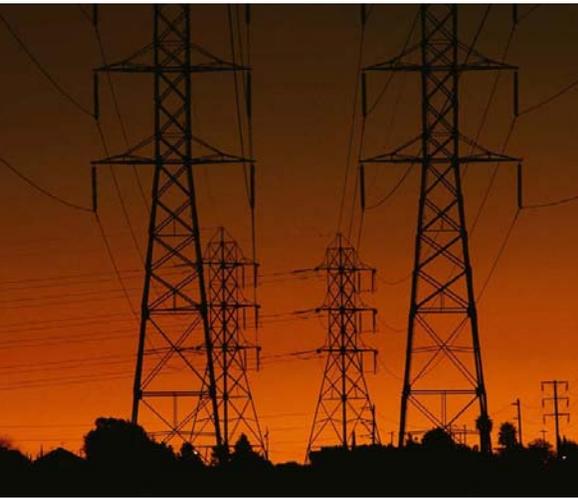
ClimAID global climate models project that average annual temperature will rise by 1.5 to 3.0°F in the 2020s compared to the 1970-1999 baseline period. An analysis of the sensitivity of energy demand to these changes shows that while heating energy use will decrease slightly, cooling energy use will increase much more.

Fuels used for residential heating in New York State by ClimAID Region



New York State Electricity Generation by Fuel Type (2008)





Particularly Vulnerable Groups

For lower-income residents, increased energy costs associated with air conditioning may be difficult to afford.

Low-income residents living in urban areas, which are already subject to urban heat island effects, may be especially vulnerable to higher energy costs.

New energy facilities to power the increased demand for air conditioning may place burdens on communities located nearby.

Elderly, disabled, and health-compromised residents are especially vulnerable to energy outages associated with extreme climate events.

Impacts of Extreme Heat in Cities

Sustained high temperatures contribute to increased energy usage during heat waves, primarily for cooling indoor space and industrial equipment. When high temperatures persist overnight during these extended heat events, the likelihood of outages increases. While the network design of local grids tends to isolate outages geographically, limiting the number of customers affected, prolonged heat waves can cause multiple outages across a city. The impacts of power outages can extend well beyond the energy sector, affecting health, transportation, and telecommunication.

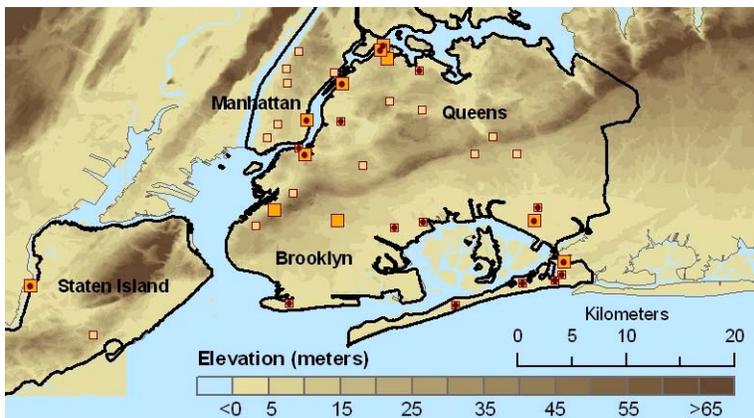
In New York City, urban heat island effects already contribute to an increase in energy demand during hot summer periods. Worsening heat waves under climate change pose a challenge for the city's energy sector. Existing urban heat island patterns will become more intense, such that areas that are already warmer due to heat island effects will become relatively hotter during a heat wave. The effects of heat islands are especially prominent in many lower income neighborhoods, such as Fordham in the Bronx and Crown Heights in Brooklyn. These neighborhoods often have fewer trees on the street and higher building density, both of which contribute to hotter conditions.

Higher poverty areas of New York City, particularly in northern Manhattan, the South Bronx, and parts of Brooklyn, have lower rates of home air conditioning than other areas, putting them at greater risk for heat-related health problems. But even households that have air conditioning in these areas may be reluctant to use it because of the high cost of energy, which represents a large portion of their household income.





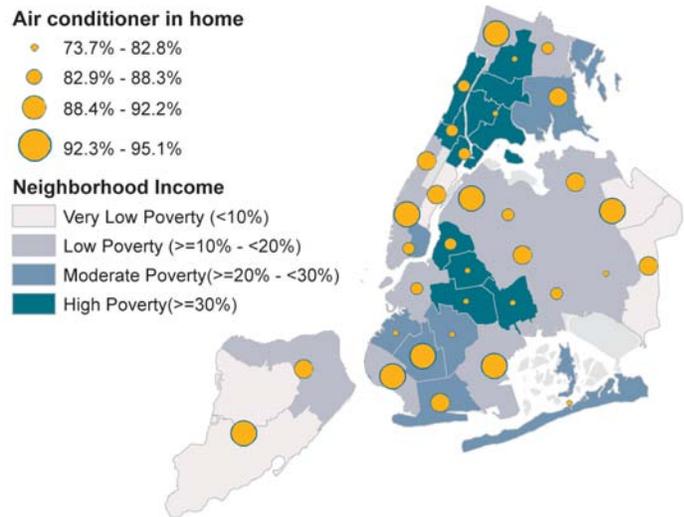
Location and elevation of power plants in New York City



The majority of New York City's power plants are located at low elevations on the coast and are thus vulnerable to sea level rise and storm surge.

- Small power plants (<100 GWh in 2000)
- Large power plants (>100 GWh in 2000)
- < 5 meters above sea level

Air conditioning distribution and neighborhood level poverty



Neighborhoods with higher poverty rates, including Central Harlem, Washington Heights, Fordham, the South Bronx, Greenpoint, Williamsburg, Bedford-Stuyvesant and others, have lower rates of in-home air conditioning than more affluent parts of the city.

To provide enough power during heat waves to meet the increase in peak demand, less efficient and more highly polluting sources of power may be used. High ozone levels due to the combination of high temperatures and air pollution are particularly harmful for the elderly and ill.

Power outages and other disruptions to supply have significant financial impacts, with costs to U.S. consumers ranging from \$119 billion to \$188 billion per year. The workforce—especially those living farther from their jobs or who are more dependent on forms of transportation that become inoperable during power outages—are likely to bear these losses. During the 2003 Northeast blackout, loss of wages was estimated to account for two-thirds of the total financial losses.

Those providing emergency services, including emergency health professionals, also may have difficulty getting to work during a power outage, thereby increasing risks to individuals in need of assistance. During the 2003 Northeast blackout, the health services sector had the second highest workforce losses as a result of business closures. Demand for emergency services during the outage increased significantly as did the rate of respiratory device failure.

To protect against severe power outages, smart grid technology can be used to help avoid them altogether by providing network operators with clearer metrics of the potential risk. Reducing demand and distributed generation (which generates electricity from many small sources) can also help lessen the risk of power outages. During heat waves and in advance of peak demand, voluntary and mandatory load-reduction programs that call for customers to reduce usage also can be employed.



Context

New York State is home to a 113,000-mile network of Interstate and State Highways including 16,000 bridges, a 4,600-mile rail network including the largest mass transit system in the U.S., some 500 public and private aviation facilities, more than 130 public transit operators, four port authorities, and numerous private ports. Transportation contributes about 10 percent, or \$100 billion annually, to the state's economy.

The highest concentration of transportation infrastructure is generally located in regions that are population centers and vital drivers of the global, national and state economy. Threats to these dense metropolitan transportation systems (especially New York City) would have far-reaching impacts.

Ground transportation systems (roads and rails) in coastal population centers are often placed underground in tunnels very close to or below sea level.

Since transportation is a networked system, delays and failures in one system can affect other systems.

Key Climate Impacts

Over the next few decades, heat waves and heavy precipitation events are likely to dominate the causes for moderate, more frequent transportation problems such as flooded streets and delays in mass transit.

By later this century, it is very likely that coastal flooding will be more frequent and intense due to sea level rise. Major adaptations are likely to be needed, not only in the coastal zones, but also in Troy and Albany as sea level rise and storm surge propagate up the tide-controlled Hudson River.

Materials used in transportation infrastructure, such as asphalt and train rails, are vulnerable to increased temperatures and frequency of extreme heat events.

Air conditioning requirements in buses, trucks, and trains, and ventilation requirements for tunnels will increase.

Low-lying transportation systems such as subways and tunnels, especially in coastal and near-coastal areas, are at particular risk of flooding as a result of sea level rise, storm surge, and heavy precipitation events.

Transportation systems are vulnerable to ice and snowstorms, although requirements for salting and snow removal may decrease as precipitation tends to occur more often as rain than snow. Freeze/thaw cycles that disturb roadbeds may increase in some regions as winter temperatures rise.

Runways may need to be lengthened in some locations since hotter air provides less lift and hence requires higher speeds for take off. Newer, more powerful aircraft can reduce this potential impact.

The Great Lakes may see a shorter season of winter ice cover, leading to a longer shipping season. However, reduced ice cover may result in an increase in "lake effect" snow events, which cause various transportation-related problems.

New York State has the most days per year of freezing rain in the nation. This affects air and ground transportation directly and also indirectly through electric and communication outages. It is unknown how climate change will influence the frequency of freezing rain in the future.





Adaptation Options

Disaster management studies have shown that every \$1 invested in preventative measures saves \$4 in losses not incurred.

Operations, Management, and Infrastructure Strategies

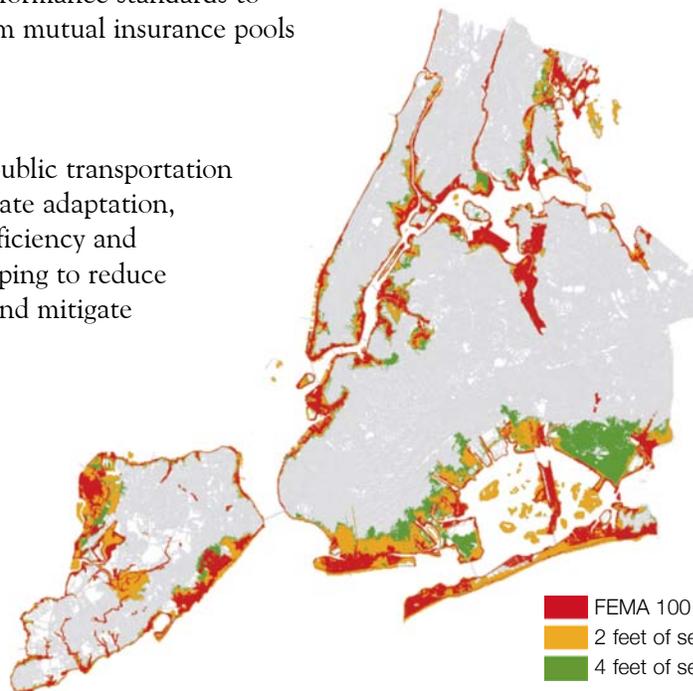
- Perform engineering-based risk assessments of assets and operations and complete adaptation plans based on these assessments, including financing.
- Protect coastal transportation infrastructure with levees, sea walls and pumping facilities; elevate bridge landings, roads, railroads, airports, and collision fenders on bridge foundations; design innovative gates at subway, rail and road tunnel entrances and ventilation openings.
- Relocate critical systems to higher ground out of future flood zones.
- Lengthen airport runways and expansion joints on bridges; upgrade to energy-efficient air conditioning on trains, subways, and buses; use heat-resistant construction materials for pavements and rail tracks.

Larger-scale Strategies

- Change standards for engineering specifications related to climate such as for heat-resistant materials and the capacity of drainage systems.
- Form alliances to set performance standards to reduce climate risks; form mutual insurance pools that spread risks.

Co-benefits

Making improvements to public transportation systems will not only facilitate adaptation, but also enhance energy efficiency and increase ridership, thus helping to reduce greenhouse gas emissions and mitigate climate change.



- FEMA 100 Year flood zone
- 2 feet of sea level rise
- 4 feet of sea level rise

NY City Streets at Risk of Flooding



As sea level rises, many more New York City streets will be at risk of flooding. The chart shows the total length in miles of NY City streets at risk of flooding under current sea level with a 100-year storm, and with 2 feet and 4 feet of sea level rise (consistent with the ClimAid projections). Under current conditions, about 11 percent of city streets are at risk. With 2 feet of sea level rise, that increases to about 25 percent. And with 4 feet of sea level rise, about 34 percent of NY City streets are at risk.

New York City's Expanding Flood Zones



100-year flood zones for the New York City area under observed conditions (red, from FEMA), with 2 feet of sea level rise (yellow), and 4 feet of sea level rise (green), as projected by the ClimAid rapid ice melt sea level rise scenario for the 2080s.



TRANSPORTATION



Particularly Vulnerable Groups

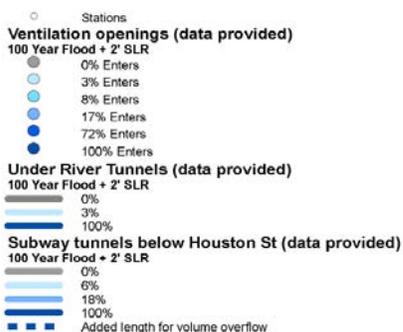
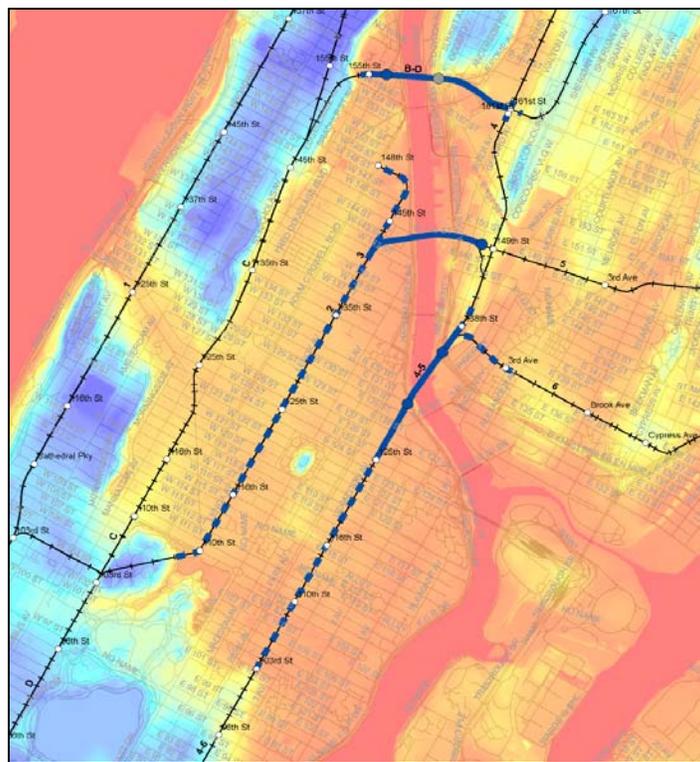
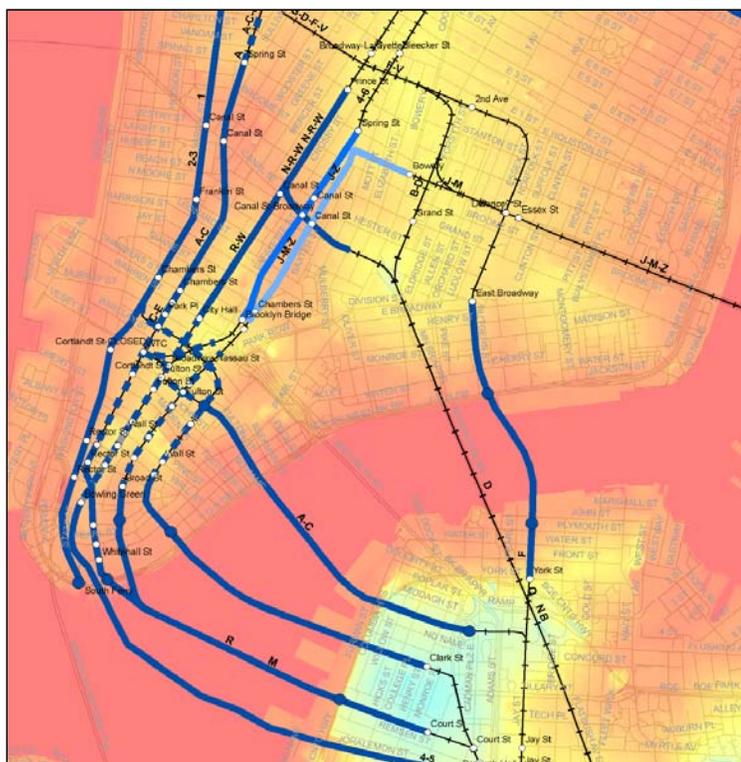
Low-income and elderly populations, especially in urban areas, are particularly vulnerable to disruption to transportation services, limiting their ability to get to work or evacuate during emergencies and extreme weather events.

Transport interruptions take a particular toll on working women, who tend to have less spare time because of child and family care and on average earn less than men.

Workers on hourly payrolls can less afford transportation-related work loss or delays compared to more affluent, salaried employees whose pay does not depend on the number of hours worked.

Lower income neighborhoods, whether rural, suburban, or urban, generally have already poor transportation options and little or no redundancy. Increases in extreme events will worsen their situation.

100-year flood with 4-foot Sea Level Rise



A 100-year flood with a 4-foot rise in sea level (consistent with the ClimAID rapid ice melt scenario projections in the 2080s) would flood a large fraction of Manhattan subways, including virtually all of the tunnels crossing into the Bronx beneath the Harlem River and the tunnels under the East River. Blue lines on the maps show flooded subway lines and tunnels. Background colors indicate topography, with areas greater than 30 feet in elevation in yellow. Since subway tracks are typically 20 feet below the street level, areas in yellow could avoid flooding given the ClimAID storm surge and sea level rise pro-



Sea level rise and a 100-year coastal storm

Impacts on New York City metropolitan area

Sea level rise in combination with coastal storm surge has the ability to severely damage transportation systems in New York-particularly those in New York City and the surrounding metropolitan region since much of the systems are located at low elevations, and some in tunnels below sea level. By the end of this century, the ClimAID projections show that sea level is expected to rise by 2 to 4 feet with significant implications for the transportation sector.

Damages from a coastal storm in the New York City metropolitan area that currently occurs on average once every 100 years would be significant. At current sea level, economic losses from such a storm would amount to about \$58 billion. Losses under a 2-foot sea level rise scenario increase to \$70 billion and to \$84 billion under a 4-foot sea level rise scenario. All sectors of the transportation system would be affected, including roads, railways, subways, airports, and seaports.

The effects of such a flooding scenario would occur rapidly. For example, many of the tunnels lying below flood heights (including subway, highway, and rail) would fill up with water in less than 1 hour. At the low-lying La Guardia airport, sea level rise would wipe out the effectiveness of existing levees, even for less severe storms. The outage times estimated for the various transportation systems range from 1 to 29 days, depending on the infrastructure and sea level rise scenario. More detailed engineering-based vulnerability assessments are needed to improve these preliminary estimates.

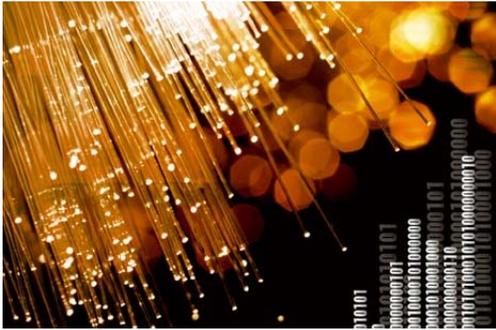
The social and economic effects of a 100-year storm would not be distributed evenly. People with limited mobility and transportation options would be affected the most, including low-income households, the disabled, and the elderly. These populations also may be less likely to access relief from centralized facilities located beyond walking distance.

To protect against the impacts of a 100-year storm, sea walls, floodgates, and pumping stations could be constructed in the short term. In the long term, transportation infrastructure could be relocated to higher elevation areas, outside of the future floodplain, and some tunnel structures could be outfitted with engineered flood protection. The sustainability of a proposed barrier system to protect the entire New York harbor has not been established and requires careful cost/benefit assessments of long-term risks and of exit strategies when prolonged sea level rise combined with coastal storm surge begins to exceed the finite design elevations of any such barrier system.

Annualized losses from the expected climate hazards for the entire metropolitan transportation systems are estimated in the hundreds of millions of dollars per year now, increasing to billions of dollars per year by mid-century. Required annual capital costs to make the transportation systems resilient to climate hazards in this coastal setting are on the order of one quarter of the expected losses that are estimated to occur if no protective adaptation measures were undertaken. Therefore preventive measures are likely to be highly cost-effective, but require engineering assessments, and must be in place before irreparable flood damage occurs. This will require capital investments.



TELECOMMUNICATIONS



Key Climate Impacts

Communication service delivery is vulnerable to hurricanes, lightning, ice, snow, and wind storms, and other extreme weather events, some of which are projected to change in frequency and/or intensity.



The delivery of telecommunication services is sensitive to power outages, such as those resulting from the increased demand associated with heat waves, which are expected to increase with climate change.



Communication lines and other infrastructure are vulnerable to heavy precipitation events, flooding, and/or freezing rain.

In coastal and near-coastal areas, sea level rise in combination with coastal storm surge flooding will be a considerable threat later this century.

Context

Telecommunications infrastructure is vital to New York State's economy and welfare; its capacity and reliability are essential to the effective functioning of emergency services as well as global commerce and the state's economy.

The sector is largely privately operated, but it has important public functions.

Because of rapidly changing telecommunications technology and deregulated, fiercely competitive markets, some operators often focus on short-term market share and profitability rather than pursuing long-term strategies to achieve reliability and redundancy.

Under current climate conditions and severe weather events, there are already serious vulnerabilities that in many instances prevent the telecommunications sector from delivering services to the public. If the sector could be made more resilient to the current climate, then the incremental threat from climate change is likely to be more manageable.

The sector is tightly coupled to the energy sector, with power outages affecting the reliability of communication services; many of its communication lines also are located on the same poles as power lines.

Modern digital technologies, including telecommunication services based on fiber optics, broadband, and the Internet, can be more vulnerable to power outages than traditional landline technology that was - or in some places still is - self-powered.

Wireless mobile phone services and landlines often share the same backbone network. In these instances, redundancy is essential to avoid simultaneous breakdowns.

Reports of service outages to federal or state regulators are not accessible to the public and are not uniformly mandatory across the different types of services.





Adaptation Options

Changes to telecommunications infrastructure to make it more robust, resilient, and redundant will reduce future climate-related outages.

Operations, Management, and Infrastructure Strategies

- Trim trees near communication lines; place communication cables underground where technically and economically feasible.
- Provide backup power at cell towers with generators, solar-powered battery banks, and “cells on wheels” that can replace disabled towers. Extend the fuel storage capacity to run back-up generators for extended times.
- Relocate central communications offices out of future flood-plains.
- Improve backup cell phone charging options by standardizing charging interfaces, including for car chargers, which allow any phone to be recharged by any charger.
- Assess, develop, and expand alternative communication technologies to increase redundancy and/or reliability.

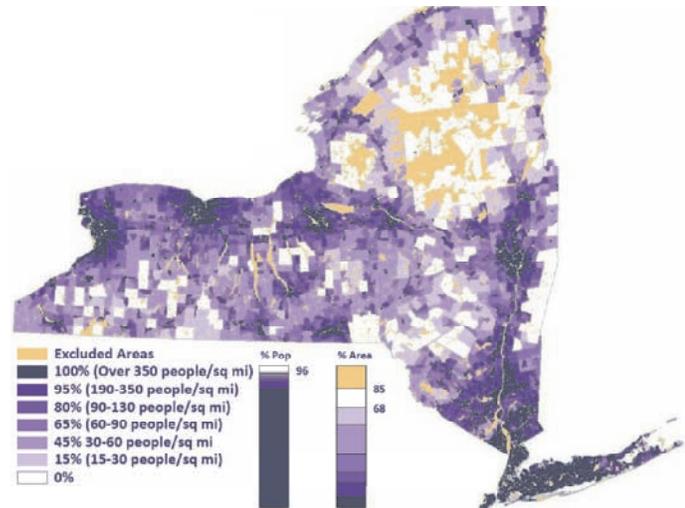
Larger-scale Strategies

- Reassess industry performance standards combined with appropriate, more uniform regulation across all types of telecommunication services. Provide better enforcement of regulations, including uniform mandatory reporting of outages.
- Develop high-speed broadband and wireless services in low population-density rural areas.
- Diversify communication media by separating cable and phone services and increasing the use of internet-based telephone services.
- Decouple telecommunications infrastructure from electric grid infrastructure to the extent possible.

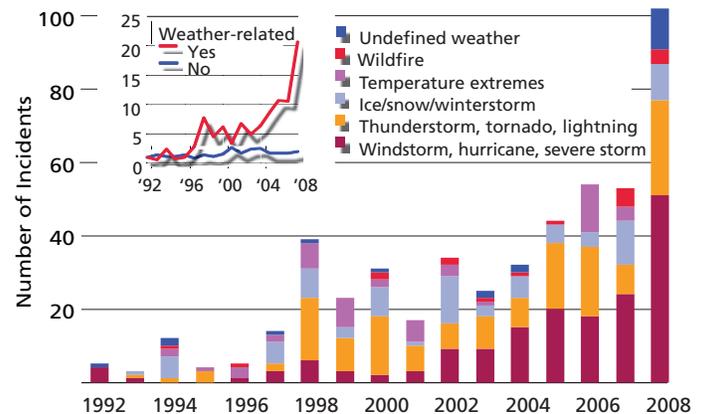
Co-benefits

Increasing redundancy and reliability in the telecommunications sector will reduce outages not only from a changing climate, but also from other non-climate related risks. Improving telecommunications technology reliability will also help to reduce greenhouse gas emissions from travel.

Cable Modem Broadband Availability - 2009



Significant weather-related U.S. electric grid disturbances



Telecommunication technologies are dependent on reliable and consistent electric power. The number of electric grid disruptions caused by extreme weather has increased ten-fold since 1992. The fraction of all grid disturbances caused by weather-related phenomena has more than tripled from about 20 percent in the early 1990s to about 65 percent in recent years. While the figure does not demonstrate a cause and effect relationship between climate change and grid disruptions, it does suggest that weather and climate extremes have important effects on grid disruptions. Projections of future increases in extreme events suggest increased risks for the electric grid and the telecommunications that depend on it.



Particularly Vulnerable Groups

Customers in rural, remote areas are more vulnerable to service disruptions than customers in urban areas, because they have fewer backup service options and often lack wireless and broadband services.

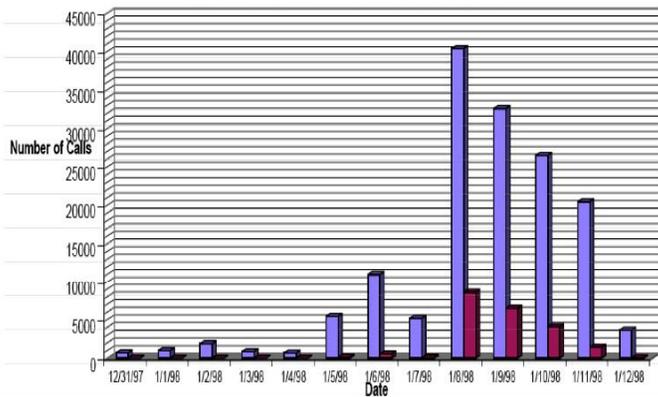
Restoration of communication services following a storm typically happens first in urban areas and then in rural areas, with smaller, remote communities likely to be restored last; this places people in rural areas at increased risk during emergencies.

Within remote, rural areas, elderly, disabled, and health-compromised populations are especially vulnerable to communication service disruptions associated with storm events due to their more limited mobility.

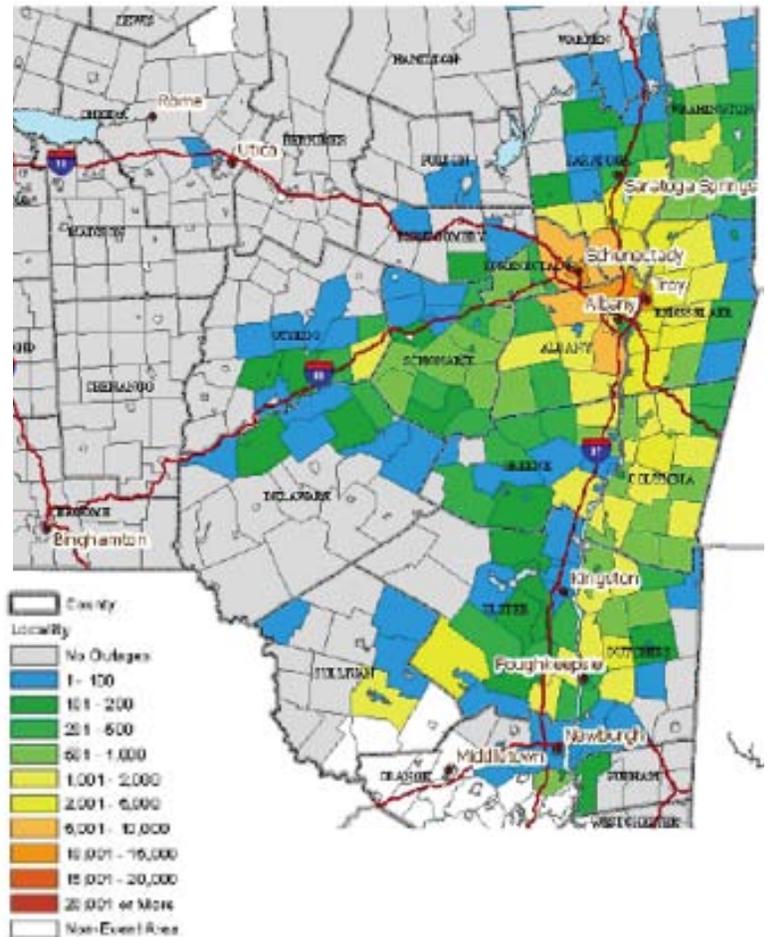
Lower-income populations are more likely to drop landline services; this increases their risk during emergency situations, as a result of their more limited communication options.

Customers Without Power by Locality - December 2008 Ice Storm

Emergency Radio Calls - 1998 Ice Storm



The chart shows the number of emergency radio calls per day (blue) and blocked radio calls (red) because of overload, in one New York state county during the 1998 ice storm. The graph covers 13 days, with a peak number of over 40,000 calls in one day. The first five days show normal background call traffic before the storm hit.

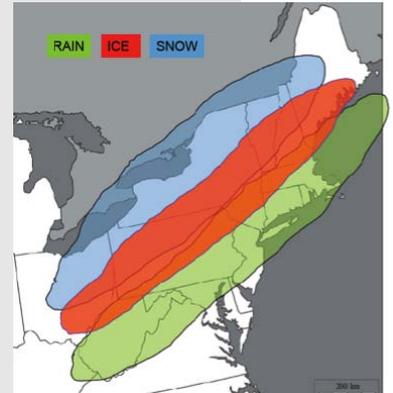




Winter Storm in Central, Western and Northern New York

Vulnerability of telecommunication services

Severe winter storms in New York generally follow this pattern: a low-pressure system moves up the Atlantic Coast bringing warm moist air that encounters cold dry air in a high-pressure system over Canada and extends into the northern parts of New York. The northward movement of the counterclockwise-rotating storm system causes warm air to overrun the cold air mass. This typically forms three moving bands of precipitation as illustrated on the map to the right.



It is uncertain how climate change will influence extreme winter storms. A hypothetical composite of historical extreme winter storms is described. While the three types of precipitation (rain, freezing rain, and snow) would not necessarily be expected to occur concurrently in these proportions, each of these types of extreme winter precipitation is currently expected to occur on average at least once per century.

- Up to 8 inches of rain fall in the rain band in near-coastal New York over a period of 36 hours.
- Up to 4 inches of freezing rain falls in the ice band in central New York, of which between 1 and 2 inches accumulates as ice, over a period of 24 hours.
- Up to 2 feet of snow accumulates in the snow band in northern and western New York over a period of 48 hours.

A storm of this magnitude could result in widespread power and communication outages, with most people who lose electricity also losing communication services. In the Central New York ice storm area, about a half million people would be without power. It would take up to 10 days to restore power to half of these customers living in the larger cities such as Albany, Binghamton, and Schenectady, and up to five weeks to fully restore services to those living in remote, rural areas. Fewer people would be affected in the western and northern New York snow accumulation area. There services may be restored more quickly, first in cities and progressing to rural areas.

Economic damages from productivity losses alone would amount to about 900 million dollars. Costs associated with direct damages - such as spoiled food, damaged orchards, replacement of downed poles and electric and phone wires, medical costs and emergency shelter expenses - would be of a similar magnitude. In total, productivity and direct damage costs would amount to about \$2 billion. These numbers, however, likely underestimate the total costs, given that a 1998 ice storm resulted in losses of about \$5.4 billion in Canada alone.

Those most vulnerable to power and communication service disruptions are those that are unable to leave their homes (those with limited transportation options) and those who lack access to cell phones, including elderly, low-income, disabled, and rural populations.

To protect against communication and power outages, trees near power and communication lines can be trimmed, backup poles and wires can be stocked to replace those that are damaged, and readiness of emergency crews to assist with restoration can be arranged in advance of storms. Increasing the fuel supply to extend the duration of emergency backup power at mobile phone cell towers with difficult road access is especially important in areas with low landline, broadband, and internet penetration.



Context

New York State relies primarily on a county-based system for public health service delivery, resulting in a decentralized system in which core services are not provided uniformly.

Information and the capacity to integrate climate change into public health planning remains limited at the local level.

Cardiovascular disease is the leading cause of death in the state and is made worse by extreme heat and poor air quality.

Childhood asthma is an important current health challenge in many parts of New York State, especially in the five counties that comprise New York City, and is made worse by poor air quality.

New York State has experienced the emergence of several vector-borne diseases (those spread by carriers such as mosquitoes and ticks) in the past few decades.

Key Climate Impacts

Demand for health services and the need for public health surveillance and monitoring will increase as climate continues to change.

Heat-related illness and death are projected to increase, while cold-related death is projected to decrease. Increases in heat-related death are projected to outweigh reductions in cold-related death.

More intense precipitation and flooding along the coasts and rivers could lead to increased stress and mental health impacts, impaired ability to deliver public health and medical services, increased respiratory diseases such as asthma, and increased outbreaks of gastrointestinal diseases.

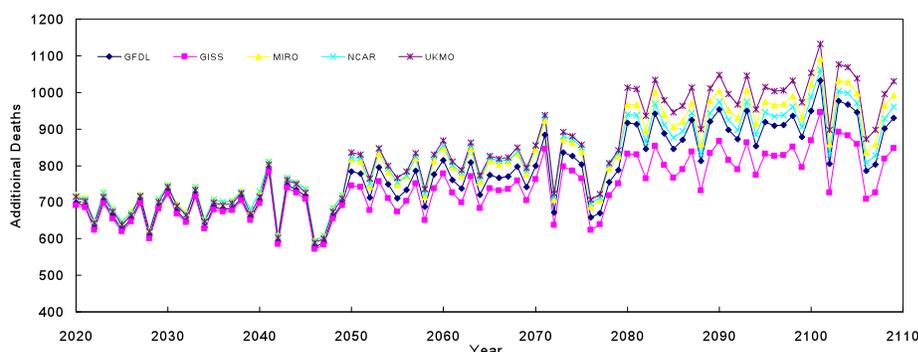
Cardiovascular and respiratory-related illness and death will be affected by worsening air quality, including more smog, wildfires, pollens, and molds.

Vector-borne diseases, such as those spread by mosquitoes and ticks (like West Nile virus), may expand or their distribution patterns may change.

Water supply, recreational water quality, and food production will be at increased risk due to increased temperatures and changing precipitation patterns.

Water- and food-borne diseases are likely to increase without adaptation intervention.

Projected Temperature-related Deaths in NY County



As climate continues to warm, heat-related deaths are expected to increase, while cold-related deaths are expected to decrease. A preliminary study of all of these temperature-related deaths from 2010 to 2100 in New York County was undertaken using 5 climate models from the set of ClimAID models under lower (B1) and higher (A2) emissions scenarios. The results suggest that increases in heat-related deaths will outweigh reductions in cold-related deaths, resulting in a net increase in deaths due to climate change. The lower-emission scenario (B1) is projected to result in substantially fewer deaths by the 2080s. The chart shows the results from 5 models for the higher (A2) emissions scenario. These results are broadly consistent with the other global climate models used in ClimAID.



Heat and respiratory problems affect those most vulnerable

Certain groups-including the elderly, low-income populations, and minorities-are more vulnerable than others to climate change-related health risks including heat-related illness and death, and decreased respiratory function.

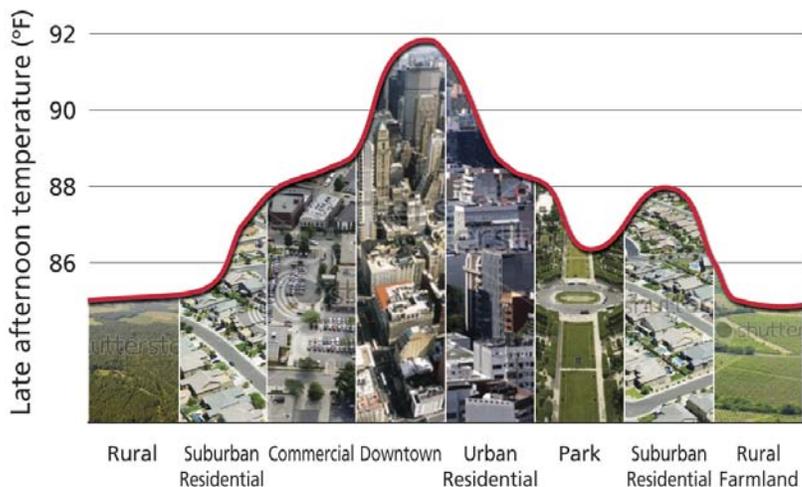
Summer heat waves have caused increased death in cities across the United States-including in New York City. Climate change will increase the frequency and intensity of heat waves. Urban areas are especially vulnerable because of the high concentrations of susceptible populations and the influence of the urban heat island effect, which makes cities hotter than surrounding areas.

Health-relevant increases in heat waves are likely to occur within 20 to 30 years, with much larger increases 50 to 100 years from now. Heat related deaths are projected to increase significantly as a result.

Home air conditioning is a critical factor for preventing heat-related illness and death. Air conditioning is especially important for elderly, very young, and health-compromised individuals, all of whom have a lower internal capacity to regulate body temperature. In New York City, about 84 percent of households had air conditioning in 2003. But, such resources are not distributed evenly across the city. Many residents living in lower

income neighborhoods lack air conditioning and are thus more vulnerable to extreme heat events. Others, including low-income elderly residents-particularly those living alone-may be reluctant to use air conditioning even if they have it due to concerns about energy costs, even during periods of extreme heat. However, air conditioning is highly vulnerable to power outages, pointing to the need for longer-term strategies to reduce heat vulnerability.

Urban Heat Island Effect

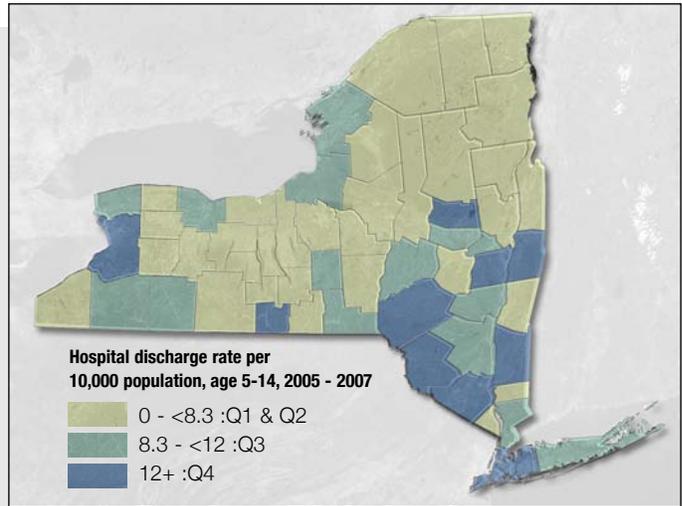


Large amounts of concrete and asphalt in cities absorb and hold heat. Tall buildings prevent heat from dissipating and reduce air flow. At the same time, there is generally little vegetation to provide shade and evaporative cooling. As a result, parts of cities can be up to 10°F warmer than the surrounding rural areas, compounding the temperature increases that people experience as a result of human induced warming.



Hospital Discharge Rate for Children with Asthma

The health effects of extreme heat events can be reduced through adaptation measures. Warning systems and outreach can be used in conjunction with providing more access to public places with air conditioning, such as offering longer hours at community centers for seniors and reducing fares on public transportation. Long-term, engineering-based strategies also can be undertaken, including tree planting, installing green or reflective roofing and insulation in public housing to reduce indoor air temperatures.

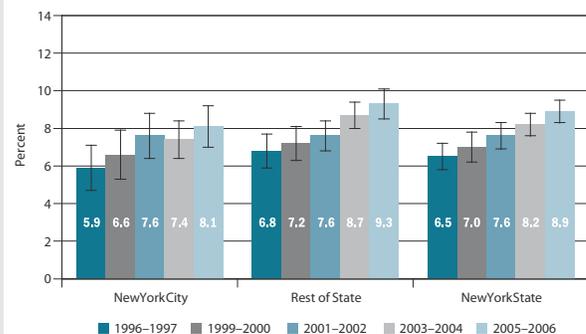


Respiratory illness and death also are likely to increase with climate change. Rising temperatures and increasing emissions will result in more air pollution, with summer ozone levels likely to increase significantly. Ozone can increase the risk of asthma-related hospital visits and death. Already, many New Yorkers live in areas in which ozone levels do not meet health standards.

Asthma is climate-sensitive as it is exacerbated by allergies and air pollution, both of which are related to climate. Childhood asthma is an important current health challenge in many parts of New York State, with many asthma events severe enough to require hospitalization. Children from lower-income families who often lack health insurance, regular doctor visits, and medications that can control attacks are more likely to have to seek hospital treatment.

African Americans and Hispanics are particularly vulnerable to decreased air quality because they tend to live in urban centers where they are more exposed to air pollutants. As a group, they are significantly more likely to be hospitalized and die from asthma than other population groups. Children, outdoor laborers, and athletes also may be at greater risk of air pollution exposure than those who spend more time indoors and are less active.

Prevalence of Current Asthma among Adults, 1996-2006



Another probable impact of climate change is increased levels of mold and other allergens that contribute to respiratory health problems. Dampness of households, a key variable for mold growth, is associated with socioeconomic status, and could intensify with projected precipitation increases. Mold may contribute to the high rates of hospitalization for asthma among African Americans in cities such as New York.

The number of adults with physician-diagnosed asthma increased between 1996 and 2006. This trend is expected to continue given ClimAID projections of rising temperatures and carbon dioxide because asthma is exacerbated by pollen and ground-level ozone. Pollen production increases under high atmospheric carbon dioxide levels, and ozone tends to increase with higher temperatures.



Conclusions

New York State is highly diverse, with simultaneous and intersecting challenges and opportunities. Among them, climate change will affect the people, sectors and regions of the state in the coming decades. Those that are already facing significant stress will likely be most at risk from future climate change. The success of the state's response will depend on developing effective adaptation strategies by connecting climate change with ongoing proactive policy and management initiatives. Climate change will bring opportunities as well as constraints, and interactions of climate change with other stresses, such as increased resource demand, will create new challenges.

The risks associated with sea level rise and coastal flooding are among the greatest climate-related challenges faced by New York State, affecting public health and ecosystems as well as critical infrastructure across many sectors including water, energy, transportation, and communication. Heat waves and heavy downpours will also affect many people and sectors. These and other drivers of climate change impacts will have a wide variety of effects that will require a range of adaptation strategies that can help reduce these impacts in the future. Such adaptation strategies are also likely to produce benefits today, since they will help to lessen impacts of climate extremes that currently cause damages. Examples of adaptation strategies in each sector have appeared throughout this report.

There is a range of adaptation needs, many of which can be undertaken in the near-term at relatively modest cost. And there are some infrastructure investments – especially relating to transportation and coastal zones – that are likely to be needed in the long-term and that would be expensive (though less expensive than the costs incurred in the absence of such measures). This suggests the need for increased and on-going interaction between scientists and policy-makers to ensure that science better informs policy, as well as the need for increased scientific and technical capabilities to be brought to bear on adaptations that involve the developing infrastructure of New York State.



Observed Climate Changes

- Annual average temperatures in New York State have risen about 2.4°F since 1970, with winter warming exceeding 4.4°F.
- Sea level along New York's coastline has risen about one foot since 1900.
- Since 1900, there has been no discernible trend in annual average precipitation for the state as a whole.
- Intense precipitation events (heavy downpours) have increased in recent decades.

Projected Changes

- Climate models with a range of greenhouse gas emissions scenarios suggest temperature increases across New York State of between 1.5 to 3°F in the 2020s, 3 to 5.5°F in the 2050s, and 4 to 9°F in the 2080s.
- Most climate models project a small increase in annual precipitation. Variability is expected to continue to be large. Projected precipitation increases are largest in winter, mainly as rain, and small decreases may occur in late summer/early fall.
- Sea level rise projections for the coast and tidal Hudson River based on IPCC methods (which do not include increased melting of polar ice sheets), are 1-5 inches by the 2020s, 5-12 inches by the 2050s, and 8-23 inches by the 2080s.
- If the melting of the Greenland and West Antarctic Ice Sheets continues to accelerate, sea level rise would exceed projections based on IPCC methods. A rapid ice melt scenario, based on observed rates of melting and paleoclimate records, yields sea level rise of 37-55 inches by the 2080s.
- Extreme heat events are very likely to increase, and extreme cold events are very likely to decrease throughout New York State.
- Intense precipitation events (heavy downpours) are likely to increase. Short-duration warm season droughts are projected to become more common.
- Coastal flooding associated with sea level rise is very likely to increase. Areas not subject to coastal flooding now could become so in the future.



Recommendations

The ClimAID process has yielded some general recommendations for potential actions that can be taken by policy makers, managers, and researchers. These recommendations can help make New York State more resilient to current and future climate risk by bringing cutting-edge knowledge and data to groups of empowered and collaborating decision makers.

Recommendations aimed at statewide decision makers

- Promote adaptation strategies that enable incremental and flexible adaptations in sectors, amongst communities, and across time.
- Identify synergies between mitigation and adaptation. Taking steps to mitigate climate change now will reduce vulnerabilities, increase resilience, and enhance opportunities across all sectors. At the same time, some potential adaptation strategies present significant mitigation opportunities while others work against mitigation.
- Improve public and private stakeholder and general public education and awareness about all aspects of climate change. This could encourage the formation of new partnerships for developing climate change adaptations, especially given limited financial and human resources, and advantage of shared knowledge.
- Analyze and address environmental justice issues related to climate change and adaptation on a regular basis.
- Consider regional, federal and international climate-related approaches when exploring climate adaptation options. This is crucial because it is clear that New York State adaptation potential (and mitigation potential as well) will be affected by national and international policies and regulations as well as state-level policies.

Management recommendations associated with everyday operations within stakeholder agencies and organizations

- Integrate adaptation responses into the everyday practices of organizations and agencies, with the potential for complimentary effects or unintended consequences of adaptation strategies taken into account.



- Evaluate design and performance standards and policy regulations based on up-to-date climate projections.
- Take climate change into account within organizational planning and development efforts.
- Identify opportunities for partnerships among organizations and agencies within the state and region.
- Create standardized, statewide climate change mitigation and adaptation decision tools for decision makers, including a central database of climate risk and adaptation information for the state that is the result of an ongoing partnership between scientists and stakeholders.

Recommendations for science and research

- Refine climate change scenarios for New York State on an on-going basis as new climate models and downscaled products become available.
- Conduct targeted impacts research in conjunction with local, state, and regional stakeholders.
- Implement and institutionalize an indicators and monitoring program focused on climate, impacts, and adaptation strategies.
- Improve mapping and spatial analysis to help present new impact data and adaptation strategies.
- Focus studies on specific systems that may be subject to nonlinearities or “tipping points.” Work should be encouraged to understand the potential for tipping points associated with climate change impacts on natural and social systems.
- Research climate variability, extreme events, and other stakeholder-identified variables of interest including ice storms, extreme precipitation events, and wind patterns.
- Build on economic cost and benefit work to create a better understanding of the costs of climate change and benefits of adaptations on a sector by sector basis.



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