A Multi-Pollutant Planning Approach

(A report provided by the Northeast States for Coordinated Air Use Management)

Frequently Used Abbreviations and Acronyms

CO_2: Carbon dioxide

EPA: U.S. Environmental Protection Agency

GGRA: Greenhouse Gas Emissions Reduction Act

GHG: Greenhouse Gas

Hg: Mercury

MDE: Maryland Department of the Environment

MPAF: Multi-pollutant Policy Assessment Framework

NAAQS: National Ambient Air Quality Standards

NESCAUM: Northeast States for Coordinated Air Use Management

NO_x: Oxides of nitrogen

SO_2: Sulfur Dioxide

SIP: State Implementation Plan

GGRA and Environmental Planning in Maryland

The GGRA Plan is part of a larger environmental planning effort in Maryland. It is the first of three key plans that the Maryland Department of the Environment (MDE) will be releasing over the next few years that use a "multi-pollutant" planning approach for selecting and analyzing the control programs that make up the plan. The GGRA Plan will not only help reduce emissions of greenhouse gases (GHGs), but will also help the State of Maryland meet its mandates to: (1) further clean up the Chesapeake Bay; (2) meet new National Ambient Air Quality Standards (NAAQS)[1] for ground-level ozone, fine particles, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2); and (3) meet federal and State requirements to further reduce regional haze as well as mercury and other air toxics.

Three key plans are the primary end products of MDE's multi-pollutant planning process. They will be developed in phases, as follows:

[1] The U.S. Environmental Protection Agency sets National Ambient Air Quality Standards for six pollutants considered harmful to public health and the environment, which are called criteria pollutants. Some of these pollutants are emitted directly into the air; others form as the result of a combination of emissions. The six criteria pollutants are: ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead.

- Phase 1: Developing the GGRA Plan, which is due December 2012
- Phase 2: Developing the State Implementation Plan (SIP) that is required by the federal Clean Air Act to implement the new ozone standard (which was revised in August 2011). This SIP will be due in 2013 or 2014.
- Phase 3: Developing the SIP that will be required by the federal Clean Air Act to meet the revised fine particle standard (expected in 2012), and will be due in 2013 or 2014.

In addition to these key phases, there are several other environmental planning efforts that will benefit from the multi-pollutant planning process established for the GGRA Plan (e.g., regional haze, and mercury and other air toxics, as previously described). The GGRA Plan is also expected to help the State with economic recovery and to help create new green jobs.

Linkages between Greenhouse Gases and Air Pollution

There are some critical linkages between greenhouse gases and other air pollutants. First, studies have indicated that climate change, if unaddressed, could cause ozone and fine particulate levels to increase.[2] Second, many strategies that are designed to lower GHG emissions, such energy efficiency programs, may also reduce emissions of NO_x, SO_2, mercury, other toxic metals, diesel, and black carbon. Third, some strategies that are designed to lower GHG emissions may result in increases in ozone-forming emissions, such as volatile organic compounds (VOCs). It therefore makes a lot of sense to work on climate, energy, criteria pollutant, and toxics issues together, not only to maximize benefits, but to also ensure that any adverse effects are minimized.

A multi-pollutant assessment approach can be an excellent way to work simultaneously to address several of these goals and concerns. Multi-pollutant planning is a term that can mean different things to different people. The next section describes how Maryland defines multi-pollutant planning.

The Multi-Pollutant Approach

Historically, air pollution problems have been addressed on a pollutant-by-pollutant basis. Each pollutant, or pollutant category, of concern (e.g., greenhouse gases, ozone, fine particulates, regional haze, and air toxics such as mercury) has required its own discrete planning effort. As today's environmental and public health challenges become more complex, states are recognizing the importance of moving to a more integrated, multi-pollutant, economy-wide approach.

A comprehensive multi-pollutant planning approach looks at multiple air quality goals concurrently and assesses potential control approaches and their environmental, public health, energy, and economic impacts together. It can assist policymakers in addressing several pollution problems in a more strategic and possibly even more resource-efficient manner. This is especially important now, as regulatory agencies are currently operating with reduced budgets.

[2] For example, see: Tagaris, Efthimios, K. Manomaiphiboon, ,K Liao, L.R. Leung, J. Woo, S. He, P. Amar, A.G. Russell. *Impacts of Global Climate Change and Emissions on Regional Ozone and Fine Particulate Matter Concentrations over the United States.* Journal of Geophysical Research, Vol. 112, D14312, 11 PP., 2007.

While the concept of multi-pollutant planning sounds simple, implementing a multi-pollutant planning approach is complex, cutting-edge, and pioneering work. Only a handful of states have been proactively engaging in multi-pollutant activities, and the U.S. Environmental Protection Agency (EPA) has only recently begun exploring how to assist states in such efforts. Maryland has been a leader, working with other Northeast states such as New York, the Northeast States for Coordinated Air Use Management (NESCAUM),[3] and EPA on multi-pollutant planning.

A multi-pollutant approach can help expand the State's vision of how various policies may be effective and yield benefits. A multi-pollutant approach that makes sense for Maryland is one that integrates climate, air quality, and energy goals. It can also conduct health and economic assessments in addition to traditional air quality assessments. Maryland's view of multi-pollutant planning is that it:

- Address multiple pollutants, including CO_2, SO_2, NO_x, and mercury
- Highlight tradeoffs and co-benefits of various policy options
- Analyze the environmental, public health, economic, and energy implications of various potential control strategies
- Allow for multi-sector analyses

The multi-pollutant approach will enable simultaneous policy and economic analyses consistent with requirements of the GGRA. It will also help Maryland integrate GHG mitigation and future air quality planning for ozone, fine particulate, and regional haze into a consolidated analytical and policy framework.

The Co-Pollutants and Co-Benefits from Reducing Them

Air pollution affects not only the quality of the air we breathe, but also the land and the water. What goes up must come down, and just like everything else, pollutants released into the air will eventually make their way down to the earth's surface.

Almost all of the control strategies in the GGRA Plan reduce GHG emissions as well as emissions of other pollutants of concern. These pollutants include NO_x, SO_2, ozone, fine particles, and mercury (Hg) and other air toxics. This section described the non-GHG co-pollutants and the benefits of reducing them.

Nitrogen Oxides (NO_x)

NO_x is a very important pollutant to reduce, as it contributes significantly to Maryland's problems with the Chesapeake Bay, ground level ozone (which is a lung irritant), fine particles (which are associated with lung and pulmonary public health problems), and NO_2 (which adversely affects the respiratory system). While most people associate Bay problems with water

[3] NESCAUM is a non-profit association of air quality agencies in the Northeast. For more information, see: http://www nescaum.org

run-off, it is important to note that approximately one-third of the Chesapeake Bay's nitrogen pollution problem is due to airborne nitrogen (NO_x emissions).

NO_x, which is primarily emitted from fossil fuel combustion at power plants, all types of motor vehicle engines, and off-road equipment, is also the primary pollutant that creates the State's long-standing problem with ground level ozone. Ozone is formed on hot summer days, when NO_x emissions combine with emissions of volatile organic compounds (VOCs) and sunlight to photochemically produce ozone. NO_x emissions also play a key role in contributing to Maryland's problems with fine particle pollution.

Sulfur Dioxide

Achieving reductions in SO_2 is also very important to public health and the environment. SO_2 is the primary pollutant contributing to unhealthy fine particle levels in Maryland. SO_2 emissions most come from fossil fuel combustion at power plants and other industrial facilities, as well as from the burning of high-sulfur fuel in off-road vehicles such as locomotives and large ships. Due to adverse respiratory effects associated with exposure to SO_2, the U.S. Environmental Protection Agency (EPA) established, and recently revised, the NAAQS for SO_2. It is also the primary pollutant linked to acid rain, as well as the main contributor to reduced visibility across the country. The Regional Haze requirements of the federal Clean Air Act are designed to address the visibility issues.

Fine Particles

By reducing SO_2 and NO_x emissions, which leads to lower levels of fine particles in the air Marylanders breathe, significant public health benefits can be created. The size of particles is directly linked to their potential for causing health problems. Fine particles less than 2.5 microns in diameter pose the greatest risk because they can lodge deep into the lungs and some particles may pass into the bloodstream. Therefore, exposure to such particles can affect both lungs and heart. Particle pollution exposure is linked to a variety of health problems, including: increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing; decreased lung function; aggravated asthma; onset of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease. Another concern with fine particles is that their adverse impacts occur year-round, versus the seasonal nature of ozone impacts.

Environmental effects of particle pollution include reduced visibility, environmental damage, and aesthetic damage. Fine particles are the major cause of reduced visibility (haze) in many of our treasured national parks and wilderness areas. Particles can be carried over long distances by wind and then settle on ground or water. The effects of this settling include: more acidic lakes and streams, changed nutrient balance in coastal waters and large river basins, depletion of nutrients in soil, damage to sensitive forests and farm crops, and affects on the diversity of ecosystems. Particle pollution can stain and damage stone and other materials, including culturally important objects such as statues and monuments.

Ozone

Reducing NO_x emissions leads to lowered ozone levels, and the associated public health benefits are significant. Ozone is a highly reactive gas that reacts strongly with living tissues, as well as many man-made substances. Volatile organic compounds (VOC), air toxics that are emitted from a variety of products, from gasoline to paints to building materials, also greatly assist in forming ozone. Ninety percent of the ozone breathed into the lungs is never exhaled, as ozone molecules react with lung tissue to cause several health consequences.

Too much ozone in the air we breathe can be harmful to people who work or exercise outdoors regularly, anyone with respiratory difficulties, and especially to our children. The most common symptom is pain when taking a deep breath. Exposure to ozone can result in long- and short-term effects in healthy individuals as well as those who are already sensitive to air pollution, such as children, asthmatics and the elderly.

Long-term ozone effects may include reduced lung function, scarring of lung tissue, and even premature death.[4] Research suggests that repeated exposure to ozone may cause damage to lung tissue, thereby reducing lung function. According to EPA, "Long-term exposures to ozone can cause repeated inflammation of the lung, impairment of lung defense mechanisms, and irreversible changes in lung structure, which could lead to premature aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis."[5]

Children are at greater risk for ozone-related respiratory problems because their lungs are still developing, they breathe more rapidly, and they play outside during the afternoons, when ozone is at its highest levels. Children also inhale more air, hence more pollution, per pound of body weight than do adults.[6] Additionally, anyone suffering from lung disease has even more trouble breathing when air is polluted with high levels of ozone. Prolonged exposure, even to relatively low levels of ozone, can even significantly reduce a healthy adult's lung function.[7]

Short-term ozone effects among healthy populations include impaired lung function and reduced ability to perform physical exercise. For example, healthy young people developed significant reduction of lung function, additional coughing and breathing pains, and enhanced airway reactivity to irritants when exposed to ozone at concentrations between 80-120 parts per billion (ppb) for 6.6 to 7.0 hours while moderately exercising.[8]

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[4] Bell ML, Dominici F, and Samet JM. *A Meta-Analysis of Time-Series Studies of Ozone and Mortality with Comparison to the National Morbidity, Mortality, and Air Pollution Study*. Epidemiology 2005; 16:436-445.

[5] United States Environmental Protection Agency. (17 July, 1997), Factsheet: EPA's Revised Ozone Standard. United State Environmental Protection Agency, Technology Transfer Network, OAR Policy and Guidance.

[6] Ambient Air Pollution: Respiratory Hazards to Children Committee on Environmental Health Pediatrics 1993 91: 1210-1213.

[7] Galizia, A. and Kinney, P.L. Long-Term Residence in Areas of High Ozone: Associations with Respiratory Health in Nationalwide Sample of Nonsmoking Young Adults. August 1999. Environ Health Perspect, Vol. 107, No. 8, pp. 675-679.

[8] Foinsbee et al., 1990; Horstman et al., 1990; McDonnell et al., 1991. Out of Breath: A Report on the Health Consequences of Ozone and Acidic Air Pollution in Metropolitan Chicago. American Lung Association of Metropolitan Chicago, October 19, 1994.

Ozone poses a threat to the health of natural ecosystems. Scientific evidence suggests that air pollution weakens the immune systems of many types of vegetation and can cause significant crop damage. In addition, rain and snow wash air pollution deposited on vegetation and architectural surfaces into the streams and rivers of the region and finally into the Chesapeake Bay.[9]

Mercury and Other Air Toxics

Airborne chemical contaminants such as mercury can also affect the Bay. Mercury is a potent air toxic that can cause serious adverse neurological effects, as well as harm the brain, heart, kidneys, lungs, and immune system. It is a naturally occurring element that is found in rocks, including coal. When coal is burned at power plants, mercury is released into the environment. It can then be deposited into Maryland's waters from through wet deposition (falling to the ground through acidic rain, snow, or fog) and dry deposition (failing to the ground by attaching to dust or smoke). Airborne mercury emissions are the primary contributor to the State's ongoing problems with mercury in water bodies as well as the resultant mercury advisories for fish.

Further reducing risk of exposure to other air toxics, such as benzene and acetaldehyde, is also critical for protecting public health. Levels of these toxic emissions, which typically come from cars and other mobile sources, have significantly declined in Maryland with the implementation of the clean fuels, advanced technology vehicles and inspection & maintenance programs. Opportunities should be explored to further reduce these pollutants.

Chesapeake Bay Benefits

One of the primary goals of Maryland's effort to reduce GHG emissions is to begin addressing sea-level rise, which could have a dramatic impact on the Bay and the living resources of and around the Bay. Chapters 1 and 2 of this Plan provide additional information on sea-level rise in Maryland.

In addition to addressing sea-level rise, the GGRA Plan can yield co-benefits that could greatly assist in Maryland's efforts to further clean up the Bay. One co-benefit is achieved by adopting strategies that reduce NO_x emissions that lead to excess nitrogen pollution in the Bay. Nitrogen is a type of nutrient contributing to the Bay's poor water quality. While nitrogen is needed for plant growth, human activities -- from driving cars to applying fertilizers -- contribute more nitrogen than the Bay's waters can handle.

According to the Chesapeake Bay Program[10], most of the nitrogen delivered to the Bay comes from:

- Airborne emissions from vehicles, power plants, industries, and other sources (33 percent);
- Chemical fertilizers applied to agricultural and urban and suburban lands, such as lawns and golf courses (26 percent);

[9] See: http://www.epa.gov/ttn/oarpg/naaqsfin/03fact html/
[10] http://www.chesapeakebay.net/nitrogen.aspx?menuitem=19412

- Treated wastewater discharged from industrial facilities and municipal wastewater treatment plants (19 percent);
- Manure from agricultural lands (18 percent);
- Septic systems that treat household wastewater and discharge nutrients into groundwater (4 percent);
- Nitrogen also occurs naturally in soil, animal waste, plant material and the atmosphere.

Excess nitrogen fuels the growth of algae, creating dense algae blooms on the surface of the water that rob the Bay's aquatic life of sunlight and dissolved oxygen. "Leftover" algae that are not consumed by the Bay's algae-eating organisms eventually die and sink to the bottom. There, they are decomposed by bacteria in a process that leaves bottom waters, with little or no dissolved oxygen that crabs, oysters and other bottom-dwelling species need to survive.

Algae can also grow directly on the grasses' leaves, further reducing the amount of sunlight they receive. Without sunlight, bay grasses cannot grow and provide critical food and habitat for blue crabs, waterfowl and juvenile fish.

Impacts on Public Health

In the 2011 "State of the Air" report for Maryland[11], the American Lung Association reported that there are 4,972 people living in the ozone nonattainment area, of whom 1,179,596 were under 18 years old and 600,352 were 65 years or older. Of these, there were

- 345,344 adult asthmatics and 140,794 child asthmatics;
- 164,878 residents with chronic bronchitis; and
- 80,337 residents with emphysema.

Given that multiple pollutants and sources cause Maryland's pollution problems, it is critical that a multi-pollutant approach to solving this problem is implemented. The GGRA Plan provides an opportunity to start this process.

Cornerstone Multi-pollutant Programs in Maryland

The State of Maryland has made considerable progress in improving our region's air quality for the criteria pollutants. Throughout the 1990's, Maryland, on average, experienced half the number of bad air quality days (i.e., days with ozone levels above the EPA national standard) than were seen in the 1980's. The summers of 2003 and 2004 were the cleanest on record since Maryland began measuring ozone air pollution. Numerous pollution controls within Maryland as well as some significant pollution controls occurring on a national level have had a major affect upon Maryland's air quality with respect to ozone.

Maryland has adopted many multi-pollutant control programs over the past five years. This section highlights three of those efforts: the Maryland Healthy Air Act, the Maryland Clean Cars Program, and the EmPOWER Maryland Program.

[11] http://www.stateoftheair.org/2011/states/maryland/

The Maryland Healthy Air Act

The Maryland Healthy Air Act (Annotated Code of Maryland Environment Title 2 Ambient Air Quality Control Subtitle 10 Health Air Act Sections 2-1001 - 2-1005) was developed with the purpose of reducing emissions of NO_x, SO_2 , and mercury from the largest coal-burning electricity generating sector (power plants). The Healthy Air Act is one of the toughest power plant emission laws on the East Coast.

The law was designed to bring Maryland into attainment with the NAAQS for ozone and fine particulate matter, while also reducing mercury emissions and deposition of nitrogen to the Chesapeake Bay and other waters of the State. The Healthy Air Act also requires that Maryland become involved in the Regional Greenhouse Gas Initiative (RGGI), which is aimed at reducing GHG emissions. The RGGI program is discussed in more detail in Chapter 7.

MDE was charged with implementing the Healthy Air Act through regulations. These regulations, which became effective on July 16, 2007, constitute the most sweeping air pollution emission reduction measure in Maryland's history.

Over 95 percent of the air pollution emitted from Maryland's power plants comes from the largest and oldest coal burning plants. The emission reductions from the Healthy Air Act come in two phases. The first phase required reductions in the 2009/2010 timeframe and of NO_x emissions by almost 70%, SO_2 emissions by 80%, and mercury emissions by 80%, compared to a 2002 emissions baseline. The second phase of emission controls will occur in the 2012/2013 timeframe. When fully implemented, the HAA will reduce NO_x emissions by approximately 75%, SO_2 emissions by approximately 85%, and mercury emissions by 90% from 2002 levels. Figures 1 and 2 illustrate the dramatic emission reductions from the 2009/2010 phase of the Healthy Air Act.

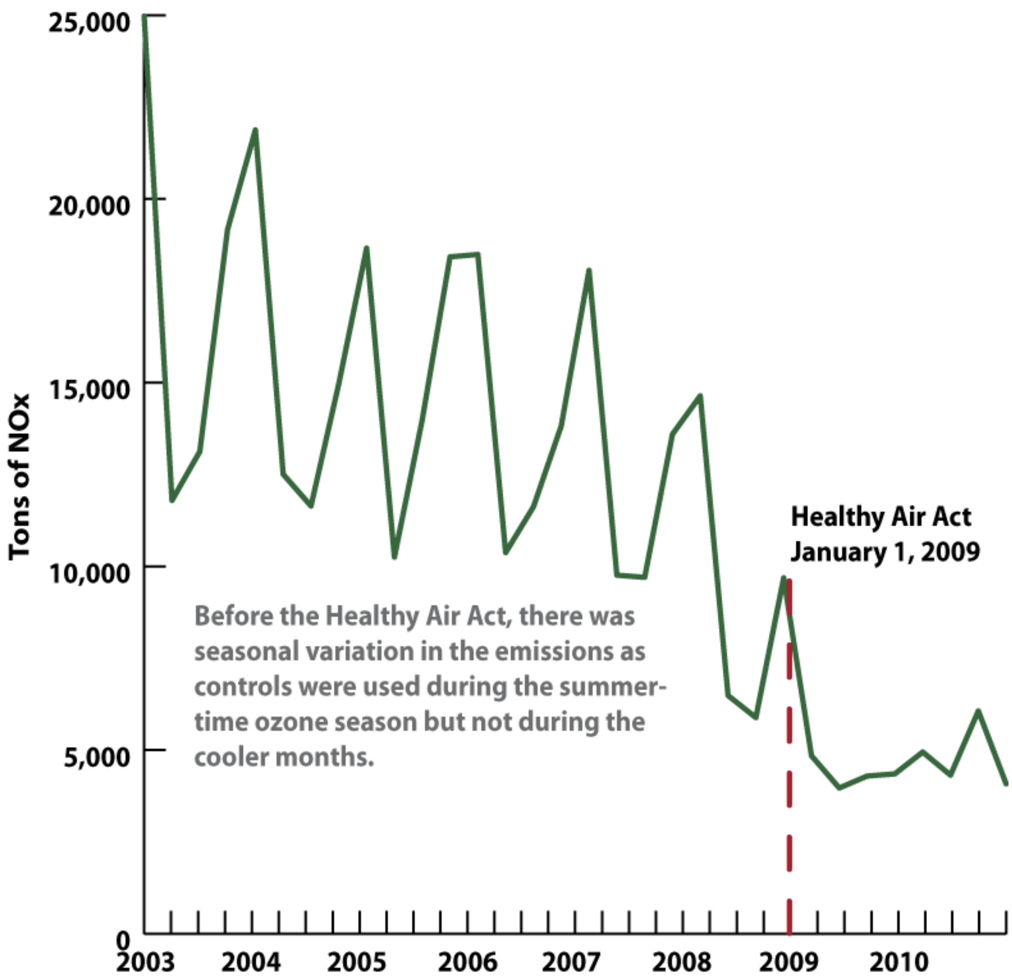


Figure 1. Emissions trend of nitrogen oxides (NO_X) between 2003 and 2011 demonstrating the elimination of a seasonal emissions peak after requirements for annual controls were put in place.

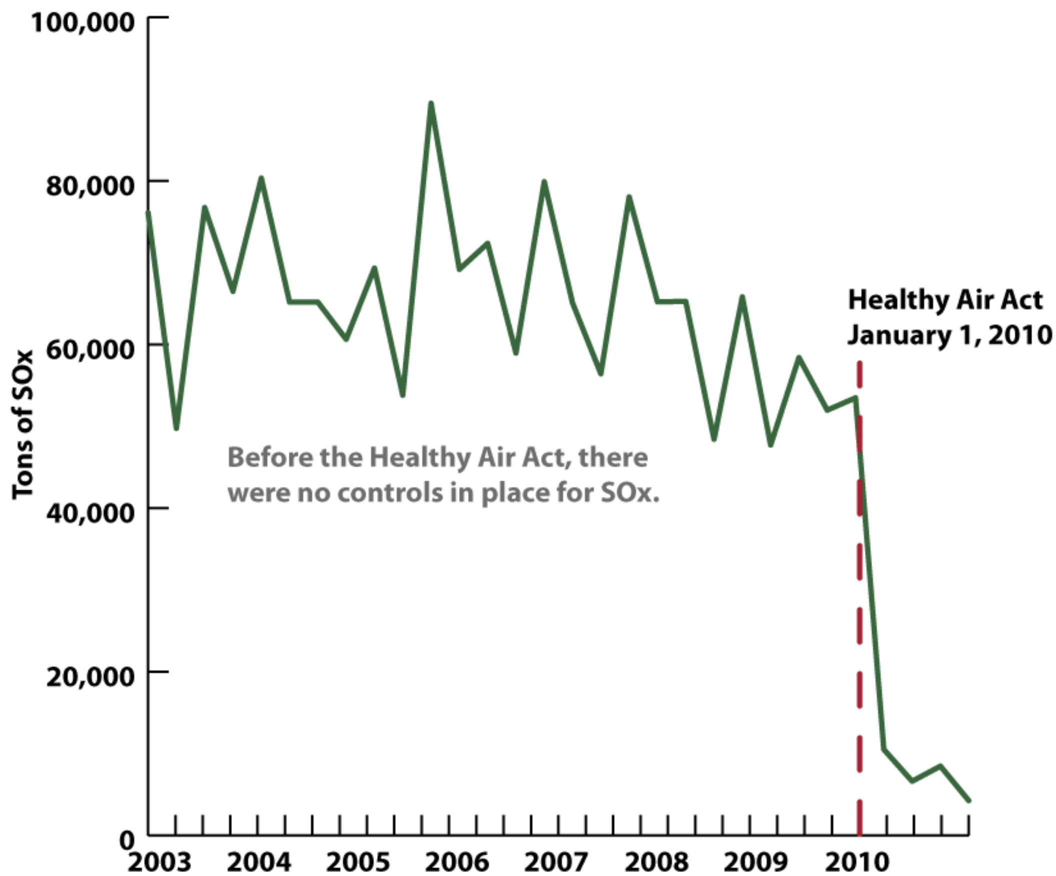


Figure 2. Emissions trend of sulfur dioxide (SO_2) between 2003 and 2011 demonstrating the sharp reduction in overall emissions after emission controls were required.

In addition to tackling the State's ozone problem, the Healthy Air Act protects the Chesapeake Bay by reducing nitrogen and mercury pollution from the air. It also helps to improve visibility throughout scenic areas in Maryland and other states.

The Maryland Clean Cars Program

In 2006, Maryland adopted the Clean Cars Act. This law requires the cleanest cars that are made to be sold in Maryland, starting with model year 2011 vehicles. It focuses on reducing emissions of four key pollutants: GHGs, NO_x, VOCs, and air toxics.

The Clean cars program helps Maryland in four important ways. First, it is a key part of the State's plan to combat global warming. Second, it helps move the State closer to meeting federal health-based standards for ozone and fine particles. Third, it reduces emissions of air toxics like benzene. Forth, by reducing nitrogen emissions and toxics, it benefits the Chesapeake Bay.

When fully implemented, the Maryland Clean Car Program is estimated to reduce emissions of GHGs by 7.8 million tons per year and air toxics by 80.2 tons per year. The CO_2 reductions provided by this program are the equivalent to removing one 1,200 megawatt coal burning power plant from the State. In addition, the Clean Car Program will reduce the emissions of NO_x and VOCs by 5.18 tons per day and 3.55 tons per day, respectively.

Figure 3 shows the dramatic emission reductions of NO_x and VOCs from mobile sources already achieved, and anticipated to be achieved, in Maryland.

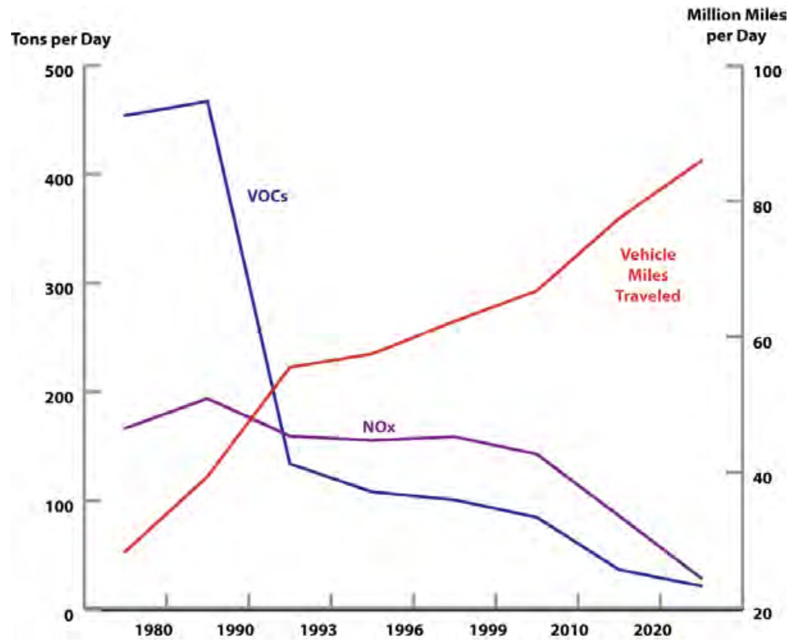


Figure 3. Emissions trends for vehicle related nitrogen oxides (NO_X) and volatile organic compounds (VOCs) demonstrating sharp reductions in overall emissions while total vehicle miles travelled (VMT) significantly increases.

EmPOWER Maryland

In 2007, Maryland launched EmPOWER Maryland as an executive initiative, setting a goal for the State government to reduce its electricity consumption by 15% by 2015. The initiative called on State government to increase energy efficiency in its operations through improved facility operations and purchasing practices, and established accountability through energy data reporting into StateStat, the Maryland statistics-based government management process.

The EmPOWER Maryland goal was broadened and codified in the *EmPOWER Maryland Energy Efficiency Act of 2008.*[12] The law established a statewide goal of reducing per capita electricity consumption and per capita peak demand by 15% from a 2007 baseline by the end of 2015. This is being achieved through a number of programs, such as utilities implementing energy efficiency programs targeted to consumers and demand-side management. The utilities' initial program plans and periodic updates must be submitted to the Public Service Commission (PSC)

[12] Md. Public Utility Companies Code § 7-211 (HB374, GA08).

for review and approval, following advisory review by the Maryland Energy Administration (MEA).[13]

Although the primary purpose of the EmPOWER Maryland Program is to reduce energy consumption, the initiative will also significantly reduce emissions of GHGs, NO_x and SO_2 from the energy generation sector, primarily power plants.

The Multi-Pollutant Policy Analysis Framework (MPAF)

As discussed previously, the non-GHG co-pollutants described above are strongly linked to energy infrastructure in many sectors of the economy. In order to maximize human resource savings, multi-pollutant planning tools are needed that can simultaneously examine policies across pollutants, sectors, and programs. To assist states in implementing a multi-pollutant planning approach, NESCAUM developed a Multi-pollutant Policy Analysis Framework (MPAF), shown in Figure 4, below. The MPAF brings together and uses a series of assessment models, tools, and databases that are linked in order to conduct multi-pollutant analysis. These include:

1. NE-MARKAL, a Northeast version of the Market Allocation model, an energy model that is widely used in Europe. U.S. EPA has a nine-region national version of this model, called US9r;
2. Regional Economic Models, Inc. (REMI), which evaluates the effects of policies on the economies of local regions;
3. U.S. EPA's Community Multi-scale Air Quality (CMAQ) model, which assesses future air quality changes for a set of policies;
4. U.S. EPA's Environmental Benefits Mapping and Analysis (BenMAP) program, which estimates health impacts and associated economic values resulting from changes in ambient air pollution.

These models, through the MPAF, can evaluate potential strategies to simultaneously address air quality and climate goals in Maryland.

[13] Links to the utilities' EmPower Maryland programs are on MEA's website at: http://energy maryland.gov/facts/empower html

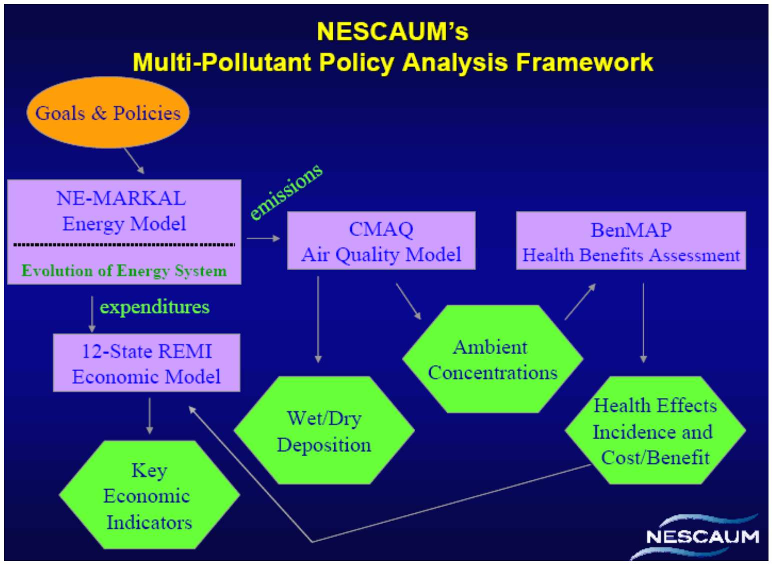


Figure 4. NESCAUM's Multi-Pollutant Policy Analysis Framework.

The centerpiece of the framework is the NE-MARKAL model, an energy model that can calculate least-cost combinations of energy technologies to achieve a prescribed pollution reduction goal. The model covers 11 states plus the District of Columbia,[14] and characterizes electricity generation, transportation, and the industrial, residential and commercial building sectors over a 30- to 50-year time horizon.

The MPAF models provide a range of outputs. In addition to assessing the potential emissions reductions of several different pollutants of concern for a given policy, it allows the user to input the outputs of NE-MARKAL (which are emissions reductions data), into other models that, in turn, can provide output data on potential air quality and health benefits. NE-MARKAL can also link to the REMI, the regional economic model, which can estimate useful economic metrics such as gross state product, jobs, and household disposable income. Such linked analyses and data that have not been traditionally currently available to air quality planners.

Furthermore, the MPAF models can help policymakers evaluate relative importance of various policies over others by assessing cross-sector impacts (e.g., how transportation programs could affect power plant outputs). It also provides data on technology evolution for modeled policies (e.g., how many and what type of electric vehicles would be needed to achieve a certain emissions reduction goal). This type of specific information on program characteristics can be very helpful to state agencies in designing future regulatory programs.

MDE has worked with NESCAUM over the past few years on multi-pollutant assessment exercises to become familiar with the MPAF tools. An earlier phase included conducting a calibration of the NE-MARKAL model so that the model behaves in a manner that replicates standard assumptions about energy and air emissions trends in Maryland. This work was

[14] The jurisdictions covered in the NE-MARKAL model include: Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.

conducted in collaboration with the Maryland Public Service Commission, the Maryland Energy Administration, and the Department of Natural Resources' Power Plant Research Project.[15]

MDE is starting this pioneering work with the GGRA goals as its primary focus, and is also keeping the other pollutants in mind. Specifically, MDE will use the MPAF to conduct "weight-of-evidence" analyses for the GGRA plan over the course of the next few years. In later phases, the MPAF will also be used when MDE commences work on the Ozone and Fine Particle SIPs.

CAVEATS

As George Box, the industrial statistician, famously pointed out in 1979, "all models are wrong but some are useful." In the context of using multi-pollutant analyses to support the GGRA plan in a weight-of-evidence role, it is useful to review the limitations that are inherent to the models used.

It is important to note that the NE-MARKAL model should not be construed as an energy forecasting tool. It is an engineering tool that is designed to explore implications of implementing possible future energy policies or scenarios. The NE-MARKAL modeling relies on a calibrated "reference case" against which those possible future energy policy or scenarios will be tested and compared. This reference case should *not* be considered as a *prediction* of future events absent major policy changes. Rather, it reflects one projection based on the standard assumptions about energy and air emissions trends in Maryland. Each time we explore an energy policy in NE-MARKAL, we call that a simulation. These simulations are then influenced by changes to these standard assumptions that reflect various policy choices.

Each modeled simulation projects technology shifts, costs, and emissions; however, these results are shaped by the database used and the assumptions or constraints placed on the model. As described above, the assumptions used in calibrating the reference case for the analyses are what the MDE, the Public Service Commission, the Maryland Energy Administration, and the Department of Natural Resource's Power Plant Research Project agreed to as the most likely *plausible* future outcome at a specified point in time. The policy simulations will examine how various system constraints, representing possible regulations or incentives, change that plausible future outcome in response to policy alternatives. An important caveat in applying these tools for policy analysis is that the accuracy of results is constrained by the underlying data. In some cases, the limitations are inherent to the availability of data. In other cases, it may be due to the quality of the data. Understanding such limitations is important in terms of placing the results in context.

Moreover, the technology shifts projected by the model should not be construed to reflect individual or societal behavior associated with risk aversion or consumer preferences. For example, the model will not recognize the economically counter-intuitive societal trend towards large cars and sport utility vehicles, (i.e., larger cars are more expensive to buy and to fuel, yet continue to outsell small cars). In order to address these issues, the model can be constrained in a manner to more realistically represent projected vehicle fleets. Input by experts knowledgeable in these types of trends is important to ensure that the modeled assumptions and constraints are reasonable and appropriate for purposes of a given policy analysis.

[15] NESCAUM, Maryland Multi-Pollutant Project; Final NE-MARKAL Calibration for Maryland, March 2011.

NE-MARKAL optimizes outcomes based on cost. Its strength is in exploring the relative cost-effectiveness of meeting various policy goals, such as limits on carbon dioxide (CO_2) emissions from power generation or performance requirements on vehicles. NE-MARKAL does not directly estimate macroeconomic effects of introducing various policies, but within the MPAF, projected costs and savings can be mapped into a regional economic model that can do that. It is, however, one of the few models of its kind at the state level that considers all energy-consuming sectors and characterizes energy use, emissions of GHGs and criteria air pollutants, technology deployment, and costs at a high level of detail. Taken together, the MPAF models provide a set of powerful tools for decision-makers to assess the relative benefits of environmental policies, viewed individually or collectively.

PROPOSED WEIGHT-OF-EVIDENCE ANALYSES FOR GGRA PLAN

The ability to assess various combinations of multi-sector strategies simultaneously is the MPAF's strength. As a weight-of-evidence analysis, our use of the MPAF is intended to complement the planning effort underway that is described in other chapters of this report. Given the caveats listed previously with respect to the MPAF's sector-specific detail, we do not plan to examine all 71 detailed strategies. However, the NE-MARKAL model is best used to assess strategies that affect the power generation sector, the motor vehicle sector, and residential and commercial energy efficiency – from where the vast majority of GHG reductions are expected to come (these sectors include more than 90 percent of the approximately 61 million metric tons (MMT) of proposed reduction potential).

Drawing from the 71 proposed strategies listed in Chapter 6, targeted technology changes envisioned for Maryland's power generation, vehicles, and residential and commercial buildings would be simulated. In order to add value to the analyses presented in the following chapters, a multi-pollutant analysis using the MPAF framework will ensure that the major elements of Maryland's GGRA plan can be implemented simultaneously without negative consequences across economic sectors (e.g., ensure that GHG reduction strategies don't set up fuel competition between sectors) while avoiding unintended consequences (e.g., ensure that increased biofuel *use* in one sector doesn't increase emissions in a different sector due to its manufacture or transportation). Because NE-MARKAL is an energy model, these analyses will be conducted considering the overall cost structure and emissions inventory associated with Maryland's energy infrastructure.

A subset of the 71 strategies will be simulated as "strategy groups" within the MPAF analyses. These will include:

1. **Residential and commercial building efficiency** – Energy efficiency represents a key low-cost, near-term opportunity for GHG reductions. By accurately representing: (a) advanced technologies for heating, cooling, lighting and other major appliances, and (b) key conservation opportunities that reduce demand for energy services associated with these same technologies (e.g., hot water heater blankets, insulation, programmable thermostats) the weight-of evidence simulations will be able to examine statewide energy savings in comparison to increased capital expenses across sectors, ensuring that fuel supply/demand relationships across sectors are balanced.

2. **Power sector strategies** – Compliance with such major programs as the Regional Greenhouse Gas Initiative, the Maryland Renewable Portfolio Standard, and achieving significant levels of power sector energy efficiency are key elements of the GGRA that account for between 16 and 25 $MMTCO_2e$ of GHG reduction potential. A highly detailed unit-by-unit analysis of power generation will ensure that compliance can be achieved while satisfying projected demand at reasonable cost. This simulation will also examine the role of potential clean imported power, renewable energy credits, and alternative compliance payments relative to in-state compliance.

3. **Light- and heavy-duty vehicle efficiency** – The current list of identified transportation technology-related strategies for the GGRA has relatively fewer reduction opportunities than the other sectors. This is because: (1) the federal government has primary authority to regulate motor vehicles and states are more limited in this regard; and (2) many of the vehicle programs are already being implemented in our assumed reference scenario. More than one-third of Maryland's GHG emissions come from the transportation sector, mostly from light- and heavy-duty vehicles. It is therefore important to accurately simulate the transportation policy approaches being considered (e.g., Maryland Clean Cars Program, Federal GHG tailpipe standards, and transit programs) to understand what and how GHG emissions can be achieved as well as to ensure the integrity of fuel supplies and cross-sector interactions (e.g., impacts on fuel price and electricity demand) in the analyses.

4. **Fuel-price sensitivity run** – This simulation will examine the robustness of the prior three simulations to cost/availability assumptions for various fuels. For example, fuel switching from coal to natural gas may be a sensible compliance strategy for RGGI if plentiful natural gas supplies are available at low cost, but offshore wind might be more practical if the costs for that energy source were reasonable in 2020.

   In addition, it will be important to look at the role of a water- and emissions- intensive drilling process in providing low cost gas to Maryland. Exogenous analysis of natural gas assumptions would further complement this simulation.

By representing the key strategies that comprise the majority of GHG reductions from the 71 strategies included in the draft GGRA plan, our multi-pollutant analysis will complement the highly detailed, measure-specific analyses that will follow by integrating and then synthesizing the collective impacts of these measures. We will also gather useful information from the NE-MARKAL model that identifies possible ways to implement the control strategies in a manner that can minimize costs and maximize economic benefit.

What Results Does the MPAF Provide?

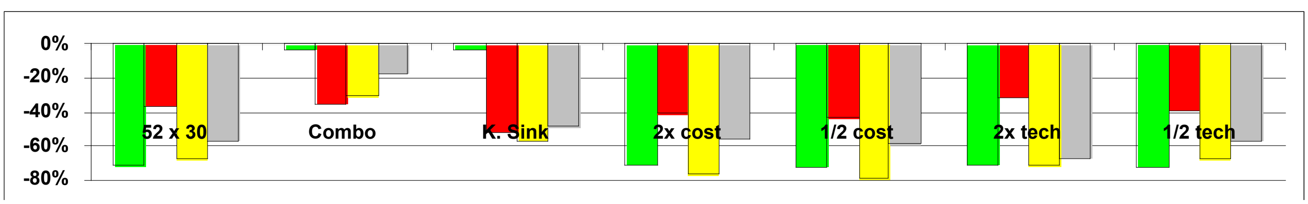
The NE-MARKAL Model

The NE-MARKAL model's strength is in its ability to look at energy and air quality issues simultaneously. The range of outputs it provides, including multi-pollutant emissions changes and costs, is far broader -- and may been more useful to high-level state decision-makers -- than the more traditional air quality analytical tools. Moreover, NE-MARKAL also provides ideas about *technology evolution* that can inform policy discussions.

The GGRA specifically requires that the State's plan must ensure no loss of existing jobs in the State's manufacturing sector, a net increase in State jobs and a net economic benefit to the State. An analysis of the projected economic impacts of various possible strategies can be conducted through the mapping of specific technology alternatives identified in a NE-MARKAL analysis (including costs and fuel savings) into the REMI macroeconomic model. REMI can then analyze job benefits within specific clean-technology sectors, as well as gross state product and overall household disposable income. At the same time, the emissions changes associated with these strategies provide information needed to understand the public health and environmental benefits that accompany each strategy or group of strategies.

For example, Figures 5 and 6 show sample NE-MARKAL modeling results, specifically emissions changes, costs, and fuel savings, for a set of hypothetical simulations of various policies under different "system constraints." These hypothetical examples are illustrative only, and do not represent actual strategies being considered for Maryland. They demonstrate how the MPAF can provide useful comparative statistics that allow decision makers to see relative costs and benefits of policy choices. The constraints used to represent different policy *approaches* (e.g., different required levels of renewable generation or electric vehicle deployment) lead to different outcomes in terms of costs and emissions. As shown in these examples, many strategies can be simulated and compared side-by-side to give decision-makers a robust visualization of the overall impacts on emissions and costs across sectors. In addition, each outcome can be tied directly back to specific *technologies*. This information will be useful for those charged with implementing a specific strategy.

Power Sector.



Transportation Sector.

Residential, Commercial, and Industrial Sector.

Net Emissions Changes.

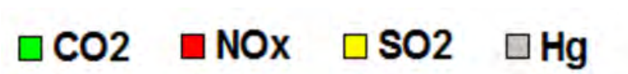


Figure 5. Projected Cumulative Emissions Changes between 2007 and 2030 by Sector under Five Hypothetical Scenarios. This shows how various modeled constraints representing different policy approaches (e.g., a stringent carbon cap, a combination of energy efficiency, renewable portfolio standard and minimum electric vehicle requirement, or a broad spectrum of measures) can lead to different outcomes with respect to emissions.

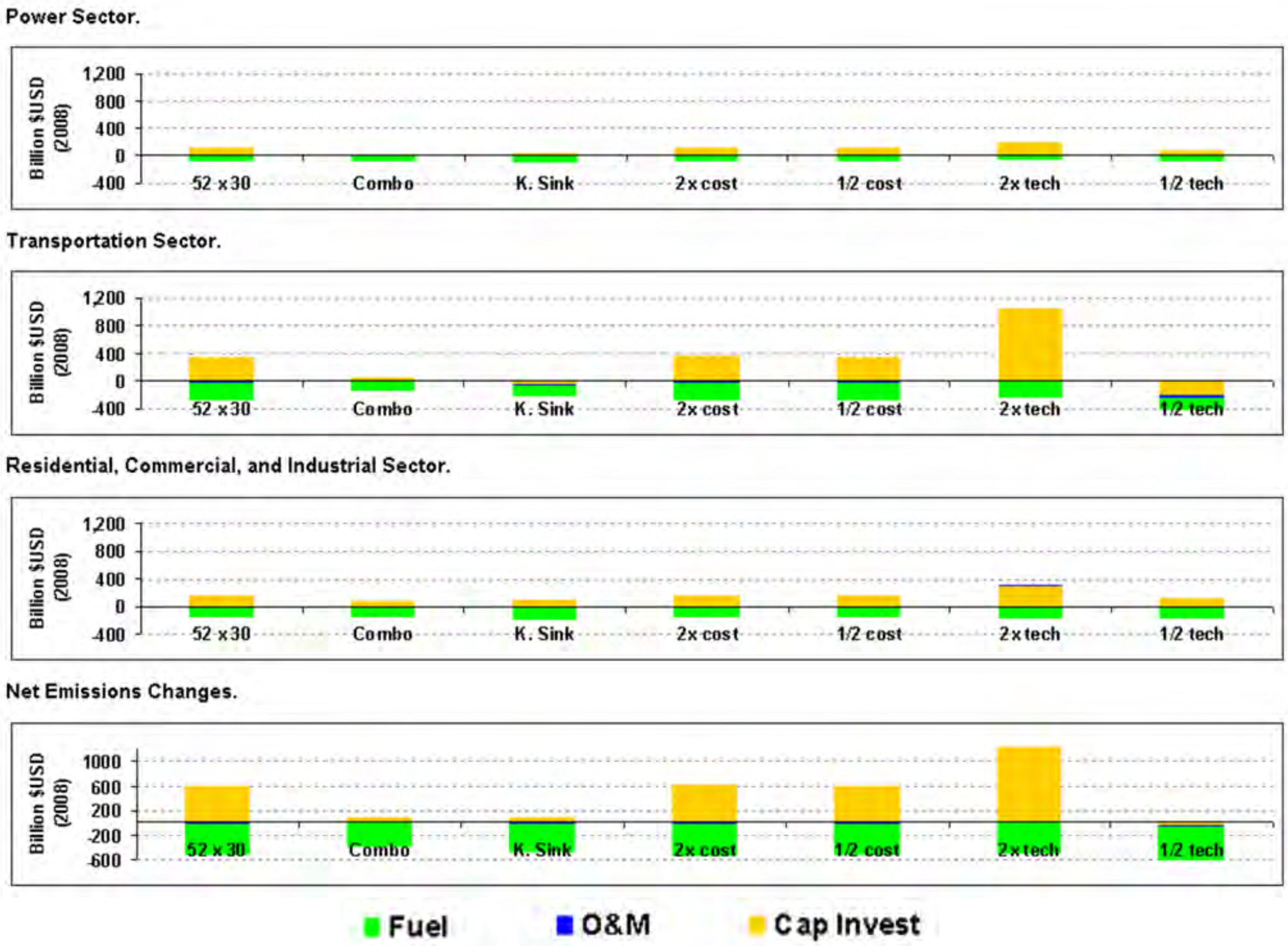
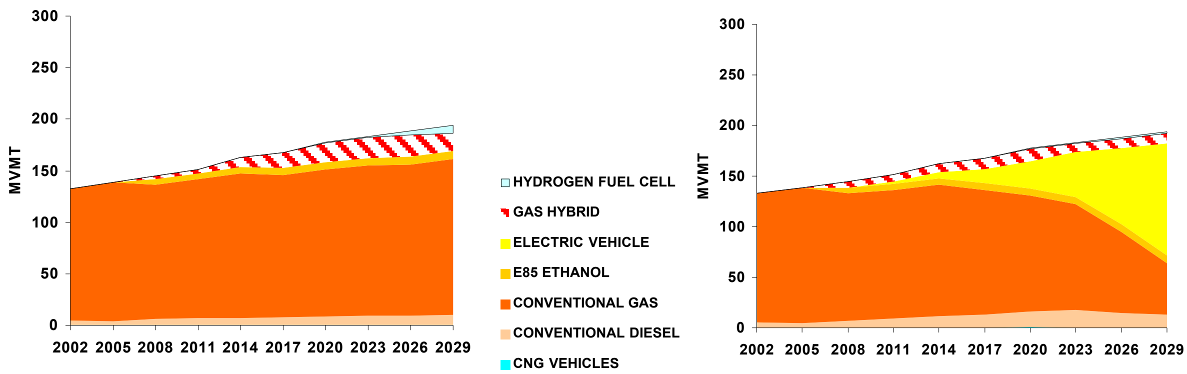


Figure 6. Projected Cumulative Cost Changes between 2007 and 2030 by Sector under Five Hypothetical Scenarios. This shows how the same policy approaches examined in Figure 5 lead to different outcomes with respect to cost and fuel savings.

Another example of the benefits of this multi-pollutant approach is that it can highlight tradeoffs across sectors, as shown in Figures 7 and 8. Figure 7 shows the evolution of light-duty technologies, by type, under a hypothetical electric vehicle program (not specific to Maryland). We simulated the program by applying a set of specific model constraints requiring a minimum



percentage of the light-duty vehicle flight to be comprised of electric vehicles. The left-hand panel shows the Reference Case, i.e., modeled results without the electric vehicle program. The right-hand panel shows the simulated effects of the program on the light-duty vehicle fleet. While the modeling indicated reduced emissions within the *transportation* sector due to the electric vehicle requirement, we note that the multi-sector NE-MARKAL model simultaneously tracked projected increases in *power sector* emissions. These projected increases result from the additional electricity demand from the transportation sector. Figure 8 illustrates the increased demand for electricity for the electric vehicle program scenario (again shown in the right-hand panel) relative to the reference case (shown in the left-hand panel). Here we see the importance of being able to track emissions and costs across sectors. This highlights for decision-makers the need for complementary policies in the power sector that are able to offset such an outcome.

Figure 7. Sample Results: Light-Duty Vehicle Technology Deployment by Vehicle Type for a Reference Case (left) and under an Electric Vehicle Program (right), expressed in terms of Millions of Vehicle Miles Traveled (MVMT) for each Vehicle Type.

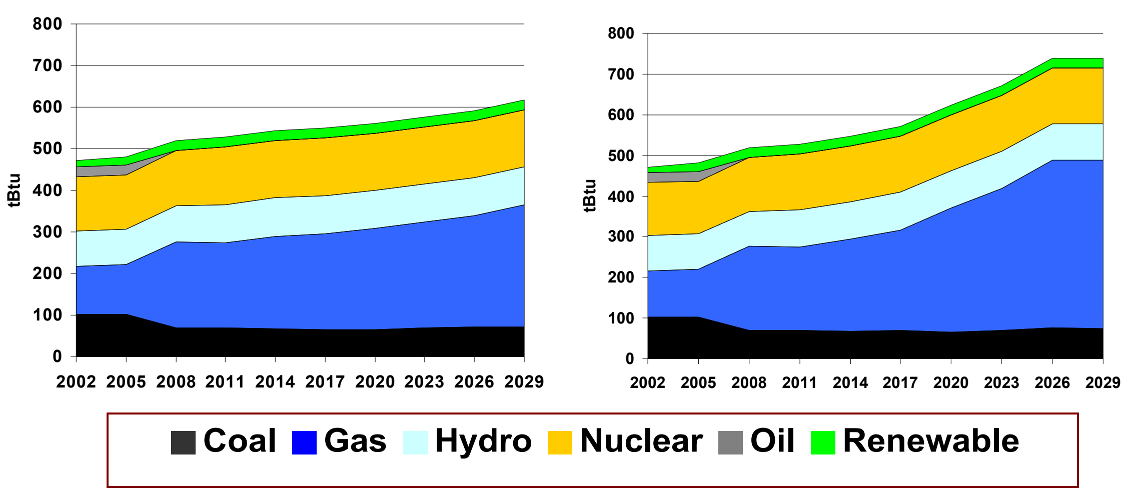
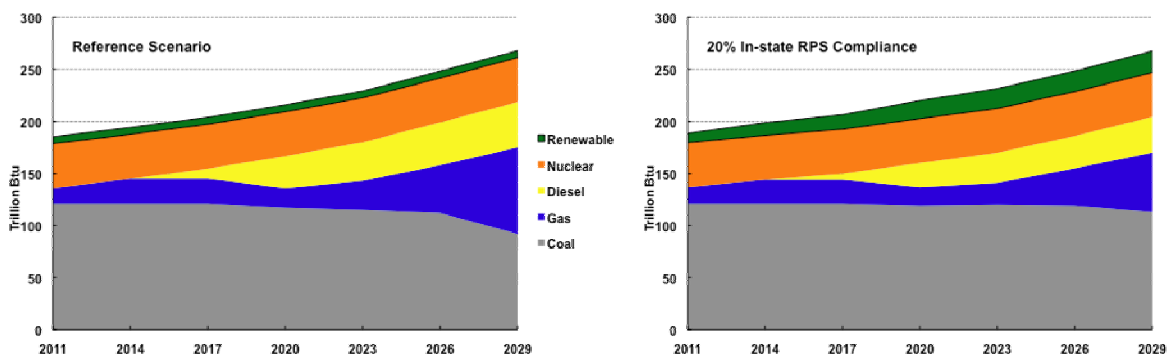


Figure 8. Sample Results: Power Sector Generation Mix by Fuel Type for a Reference Case (left) and under an Electric Vehicle Program (right), expressed in terms of Trillion British Thermal Units (tBtus) of Heat Content. Note that new natural gas generation was found to be the marginal fuel of choice and chosen to satisfy the extra electricity demand for the transportation sector.

In 2010, a preliminary NE-MARKAL analysis was conducted for Maryland's Renewable Portfolio Standard (RPS). This regulatory program is complex. It includes: (1) a "solar carve out," which means that a specific portion of the standard must be achieved by deploying solar technologies; and (2) an "Alternative Compliance Payment" (ACP) mechanism, which allows power producers to make payments to the State in lieu of deploying renewable generation. Here, we explore some draft results from that preliminary analysis to show the range and type of data that the NE-MARKAL model can produce, as well as how these data could feed into subsequent MPAF analyses for the GGRA plan.

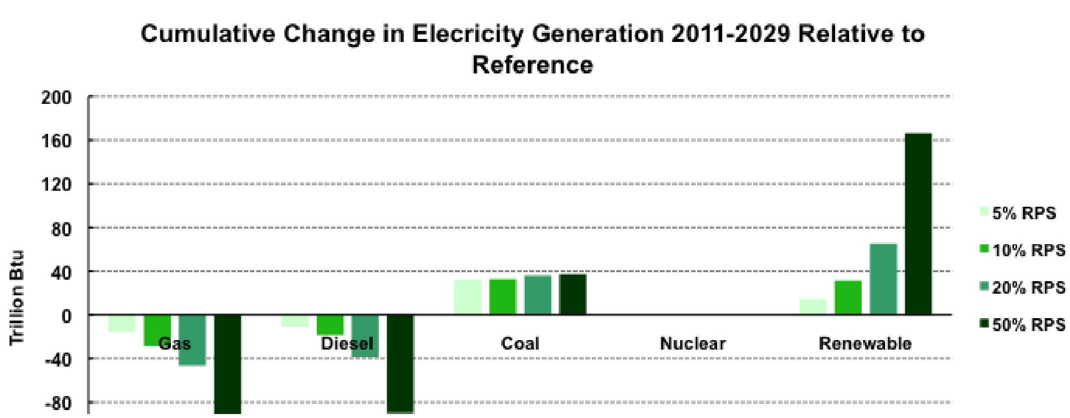
Figure 9 shows how compliance with the RPS would generally affect the State's electrical generation mix. The left-hand panel shows the reference case, and the right-hand panel shows the evolution of the power generation mix assuming that 20% of the RPS is met through in-State deployment of renewable generation technologies. This figure shows that the model projects a shift of existing power generation resources toward greater use of renewable options in the future.

Figure 9. Maryland-specific Simulation Results Demonstrating Generation Mix Projections for the Reference Case (left) and Assuming 20% In-



State Compliance with RPS Targets (right).

Depending upon the cost of Alternative Compliance Payments[16], power companies will make different decisions regarding how they deploy new in-State renewable capacity. NE-MARKAL can easily examine a wide range of in-State renewable technology deployment, as well as their associated costs and emissions. Figure 10 shows the projected changes in electricity generation associated with different levels of renewable technology deployment, specifically five, 10, 20, and 50 percent, over the next two decades. The four bars on the right-hand side of Figure



[16] The a

10 present the overall levels of renewable technology deployment.

Figure 10. Maryland-specific Preliminary Simulation Results Demonstrating Alternative Technology Pathways for RPS under a Range of In-State Compliance Targets.

The NE-MARKAL model can also provide information on how this technology deployment would break down by type, as shown in Figure 11. In addition to the technology evolution shown, NE-MARKAL can also show the costs and emissions associated with the various compliance pathways.

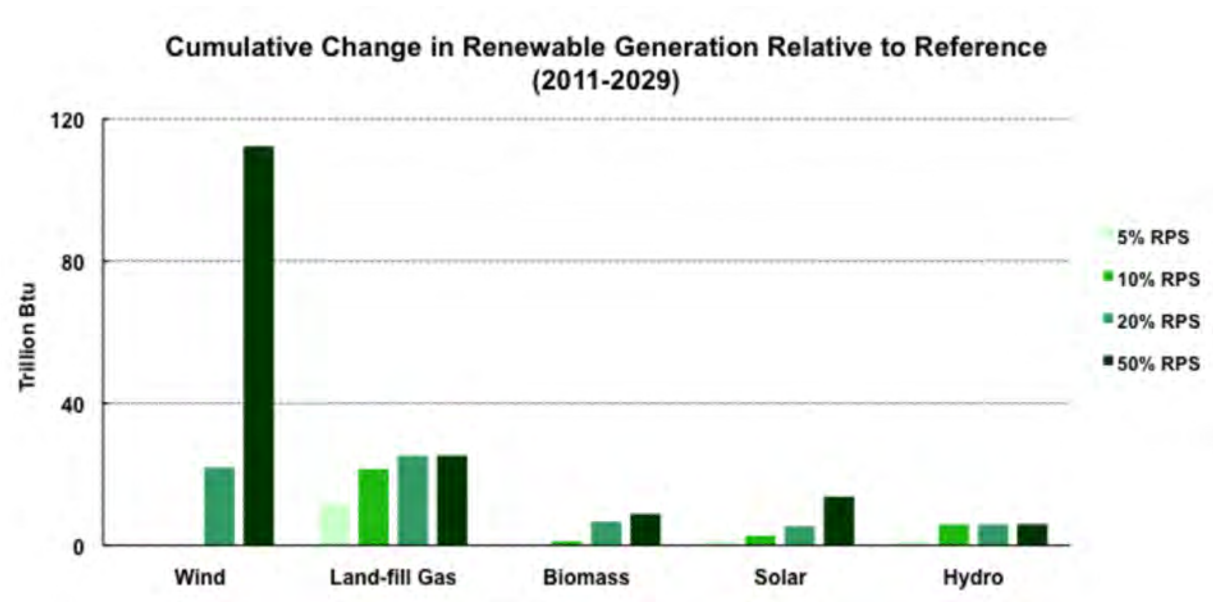
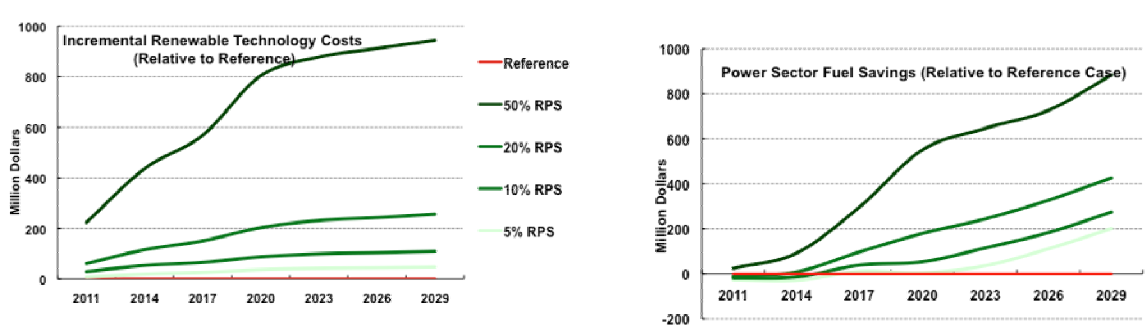


Figure 11. Maryland-specific Preliminary Simulation Results: Renewable Technology Deployment as a Function of In-State Compliance Level for RPS Targets.

In terms of costs, a key feature of NE-MARKAL is that it allows decision-makers to quickly understand program costs for a variety of least-cost pathways that assume various future market conditions. Figure 12 provides an example of this. The left-hand panel shows the modeled additional capital cost associated with achieving the RPS policy with different levels of in-State compliance. The right-hand panel shows corresponding fuel savings that are projected to accrue when new renewable generation displaces fossil-generation. As the Figure shows, these costs and savings are of similar magnitude, suggesting that the overall program costs are not large.

Figure 12. Maryland-specific Preliminary Simulation Results: Renewable Technology Costs as a Function of



In-State Compliance Level for the RPS Targets.

Linking the NE-MARKAL Model to the Other MPAF Models

The detailed information derived from NE-MARKAL simulations such as those shown above – including specific technologies used, their costs, fuel consumption and savings, and emissions changes by pollutant – can all be used as inputs to other models within the MPAF family of models. The cost information can be used to drive the REMI (regional economic) model to better understand the macroeconomic implications of various compliance pathways on gross state product, household disposable income, and jobs. The fuel and emissions information can be used in GHG planning as well as to drive the chemical transport models that simulate air quality for the criteria pollutants and regional haze SIPs mentioned at the outset of this Chapter. The modeled air quality improvements resulting from specific strategies can then be input into the public health assessment model of the MPAF to estimate changes to various health endpoints tracked by these tools.

The multi-sector nature of NE-MARKAL will ensure that analysis of the key drivers for change among the 71 identified GHG reduction measures is conducted within the broader context of the State's energy system. This will ensure that fuel supplies are balanced, unintended consequences in other sectors are tracked, and that air quality tradeoffs between pollutants are tracked and considered.

SUMMARY

The multi-pollutant approach and the MPAF analyses in particular examine multi-pollutant benefits and tradeoffs through data. It provides illustrative results of the relative importance of various modeled strategies. The MPAF is a pioneering tool, providing linked analyses and data that are not generally available to planners through their typical State planning efforts. Moreover, it provides: (1) specific information on program characteristics from the NE-MARKAL technology evolution analyses that can be used directly in future air program planning analyses, as well as in regulation development and implementation; and (2) the capability to more easily identify influences and interactions of an individual strategy with the other strategies in the suite of strategies that are modeled.

Working from a combined energy, environmental, and economic platform will be very useful in examining and choosing a set a strategies that can assist us in meeting not only the GGRA goals, but also Maryland's Bay protection and air quality goals.

NESCAUM's Multi-Pollutant Analysis for Maryland: Initial NE-MARKAL Results

Jason Rudokas, Leah Weiss, and Gary Kleiman
NESCAUM

A Progress Report Prepared for
Maryland Department of the Environment
December 6, 2011,
Updated January 11, 2012

Context of Results

- NESCAUM is providing a "weight-of-evidence" analysis of key Draft GGRA Plan measures. These are results from initial NE-MARKAL runs.
- Modeling was conducted based on the 9/6/11 Analysis Plan, and reflects an initial set of assumptions and constraints.
- The NE-MARKAL model is used in an iterative manner. These initial results provide a basis for refinement with guidance from MDE.
- All results should be considered draft preliminary.

Modeling Status

- Reference case refined and initial scenario results represented in the model.
- Sector-by-sector scenarios analyzed and compared to the reference case:
  - Power
  - Transportation
  - Buildings

Power Sector
Reference Case and Scenarios

Introduction to Power Sector Scenarios

- **Key Reference Case Inputs**
  - **AEO Reference Case Price Forecast**
  - **AEO High World Oil Price Forecast**
  - **New Power Plant Cost Data**

- **Key Reference Case Outputs**
  - **Generation, Capacity, CO_2 emissions**

- **RGGI (only) Scenario**
  - **In NE MARKAL, RGGI aims to reduce GHG 10% by 2018 relative to 2008**
  - **Maryland is expecting between 12 and 17 tons of GHG reductions by 2020**

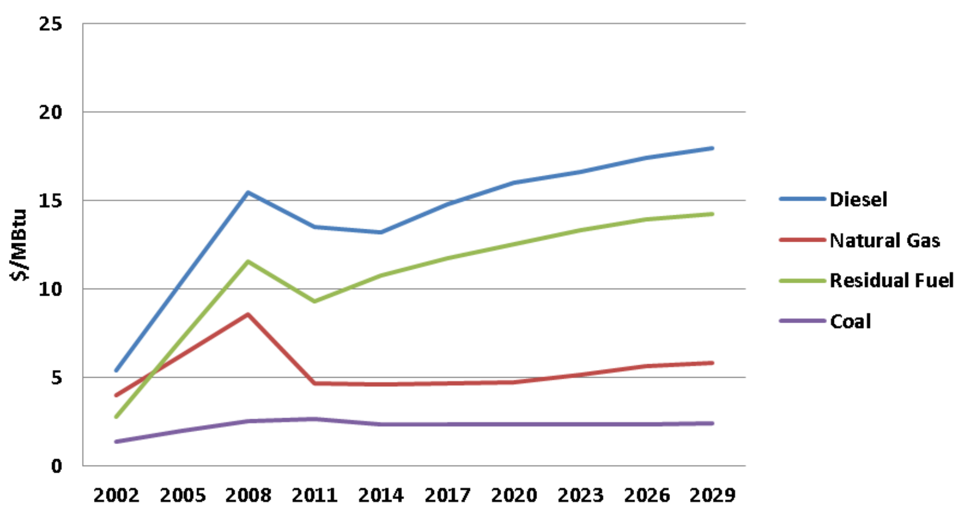
- **RPS (only) Scenario**
  - **Qualified sources to generate 20% of electricity by 2022**
  - **20% of this target is to be met in-state**

- **Generation Portfolio Standard (only) Scenario**
  - **Average carbon intensity of electricity purchased in Maryland not to exceed 1,125 lbs CO_2 / MWh**

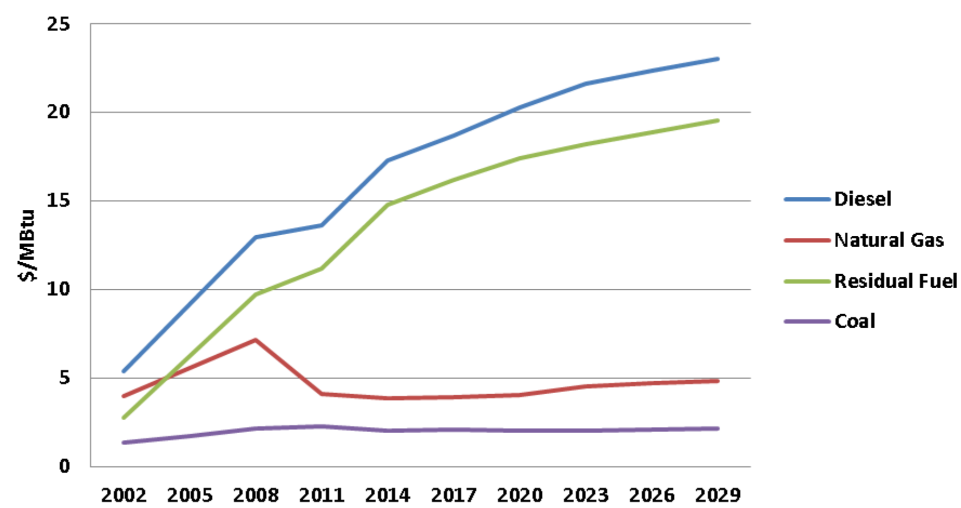
- **Interactive Scenarios**
  - **RGGI + RPS**
  - **RGGI + RPS + GPS**

Reference Case Inputs: Range of NE-MARKAL Input Price Assumptions

AEO 2011 Reference Case



AEO 2011 High Price



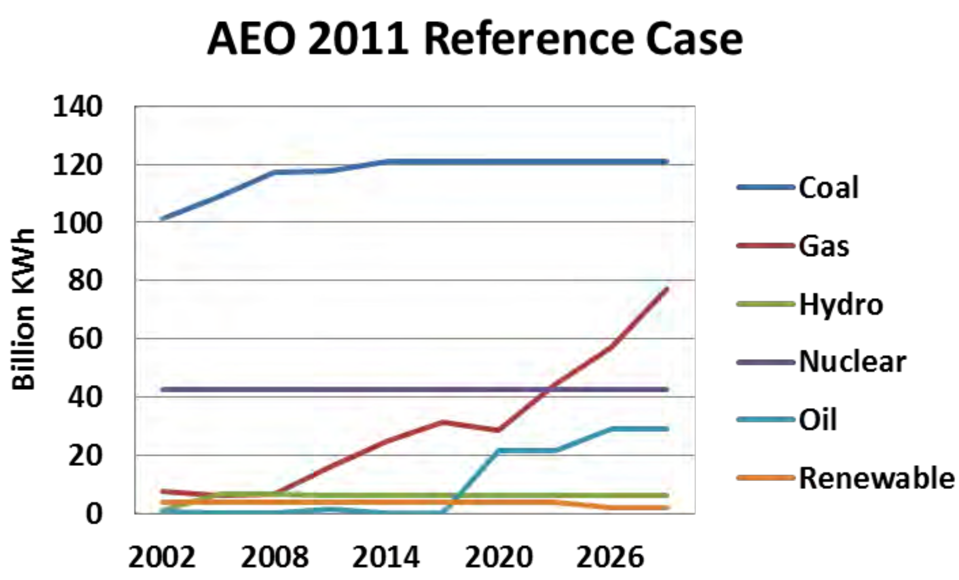
Reference Case Inputs: New Power Plant Investment Cost Assumptions

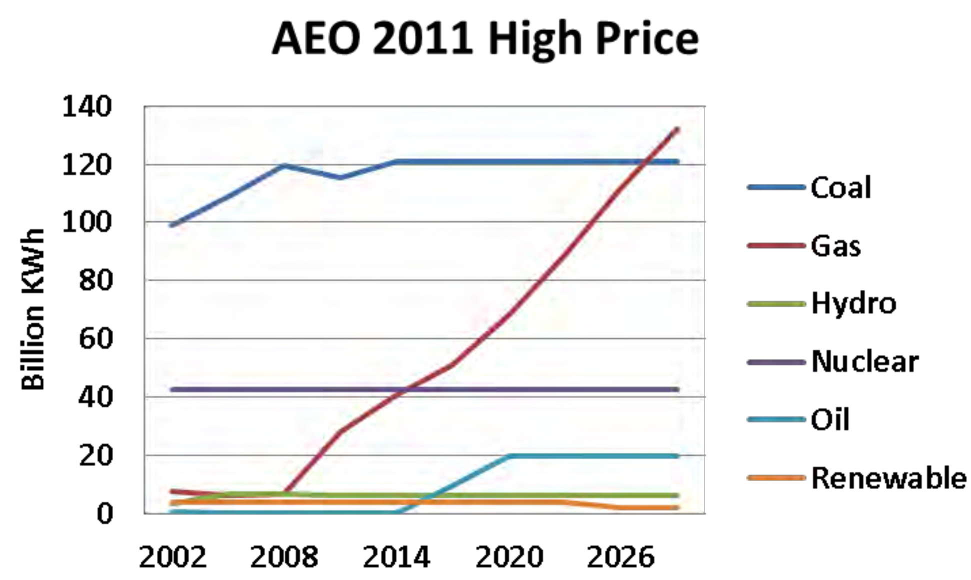
Generation Type	Fuel	Investment Cost ($/kw)
Scrubbed Pulverized Coal	Coal	1,374
IGCC	Coal	1,561
IGCC w/ Sequestration	Coal	2,279
Oil Steam Turbine	Distillate	1,024
Conv Combustion Turbine	Gas	396
Adv Combustion Turbine	Gas	372
Conv Gas/Oil Comb Cycle	Gas	577
Adv Gas/Oil Comb Cycle	Gas	566
Adv CC w/Sequestration	Gas	1,149
Fuel Cells	Gas	4,304
Advanced Nuclear	Nuclear	2,255
Pumped Storage	Electricity	2,180

Caveats: Power Sector Scenarios

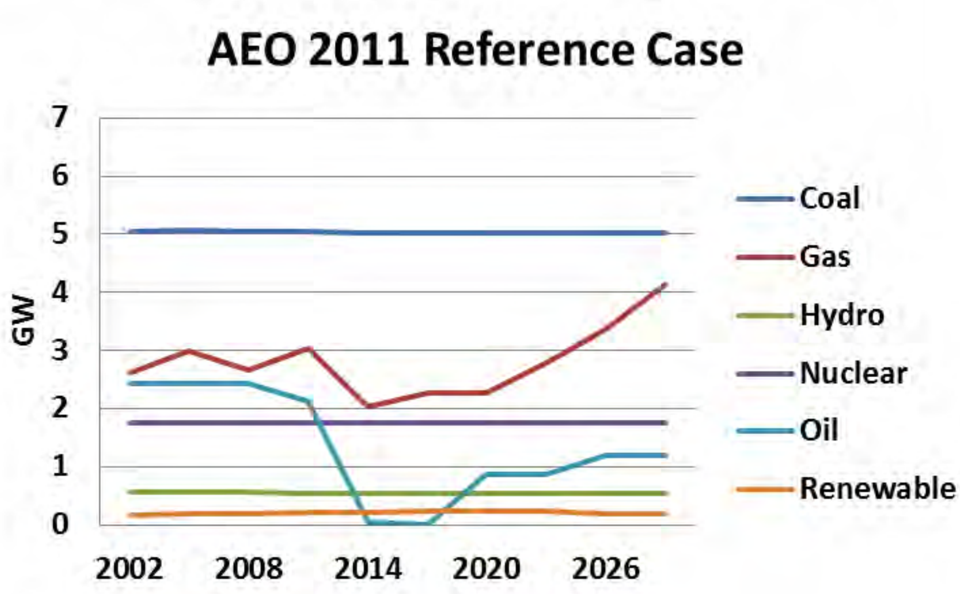
- Reference case CO_2 emissions projection
  - Historical data from RGGI Inc. 2006-2010 shows a declining trend in CO_2 emissions.
    - Real world implication is that CO_2 reductions required to meet the original RGGI cap are not as great as expected in 2006 when the state budgets were first designed.
  - NE-MARKAL shows an increasing CO_2 emission trend over the modeling timeframe.
    - Reasons for this include:
      - No EE or demand response in reference case
      - Economic downturn not entirely captured in reference case demands
    - This implies overstated CO_2 reductions required to meet the RGGI cap.
  - Discussion topic: The current RGGI CO_2 reductions projected by NE-MARKAL are in-line with expectations but not with historical observations. Should we revisit baseline CO_2 projections?
- RGGI / RPS Interaction
  - When RGGI and RPS are modeled, we do not see additional CO_2 reductions beyond RGGI that are attributed to renewable generation.
  - The RPS constraint shifts technology deployment toward renewables.
  - Note: The model is constrained so that 20% of the RPS is met with in-state resources.

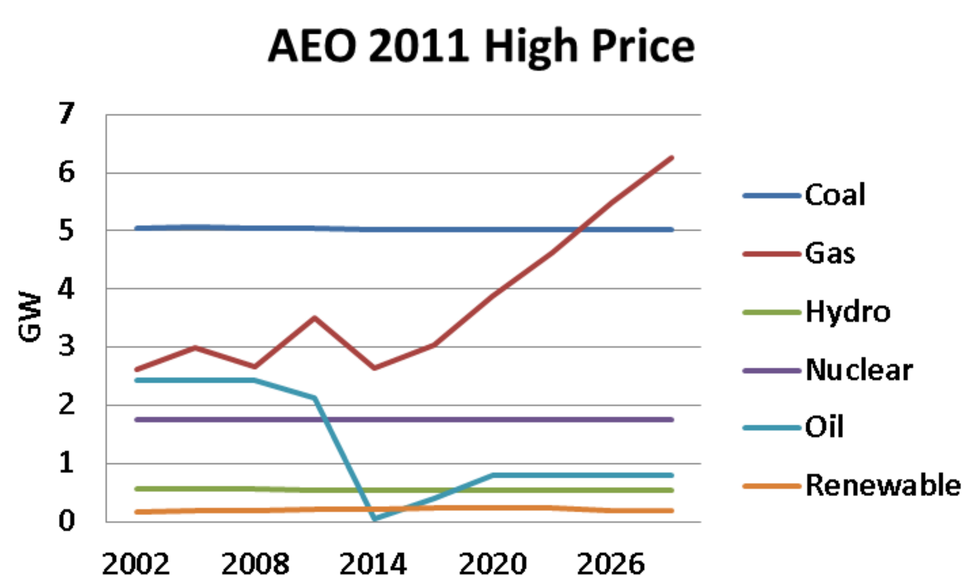
Reference Case Outputs: Electricity Generation





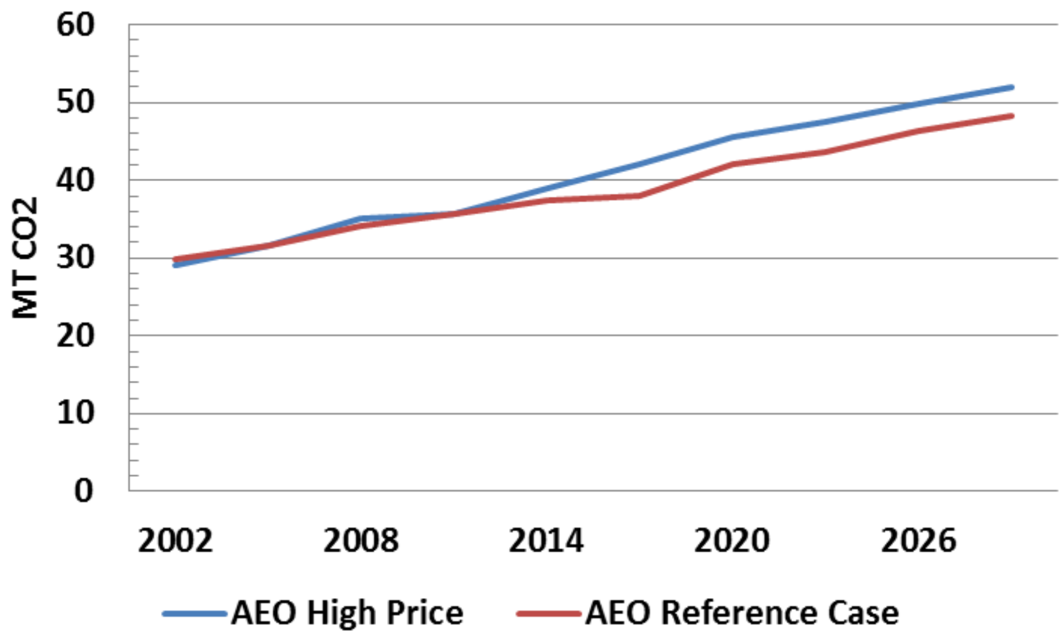
Reference Case Outputs: Electric Capacity



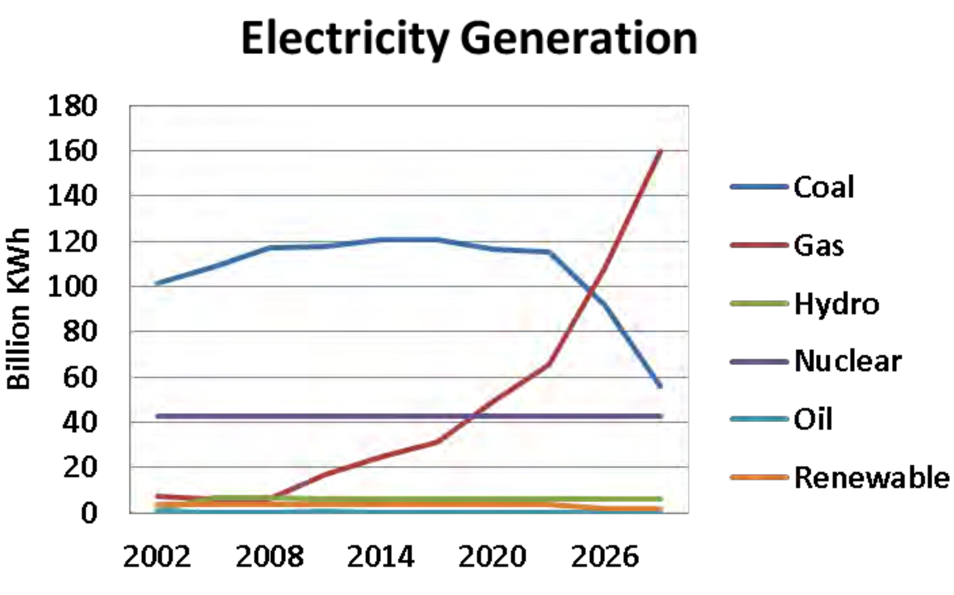


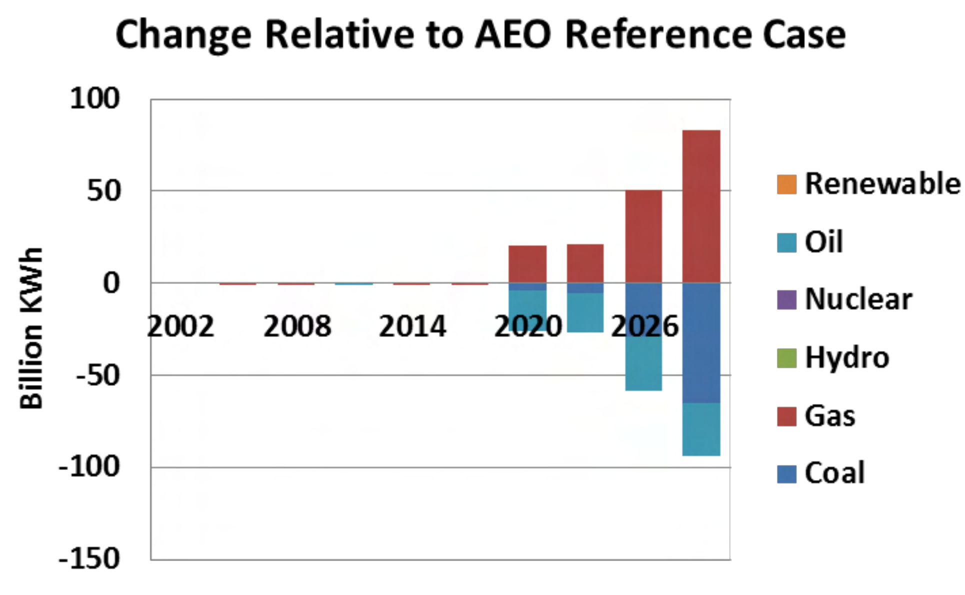
DRAFT PRELIMINARY RESULTS – FOR DELIBERATIVE PURPOSES ONLY.

Reference Case Outputs: Power Sector CO2 Emissions

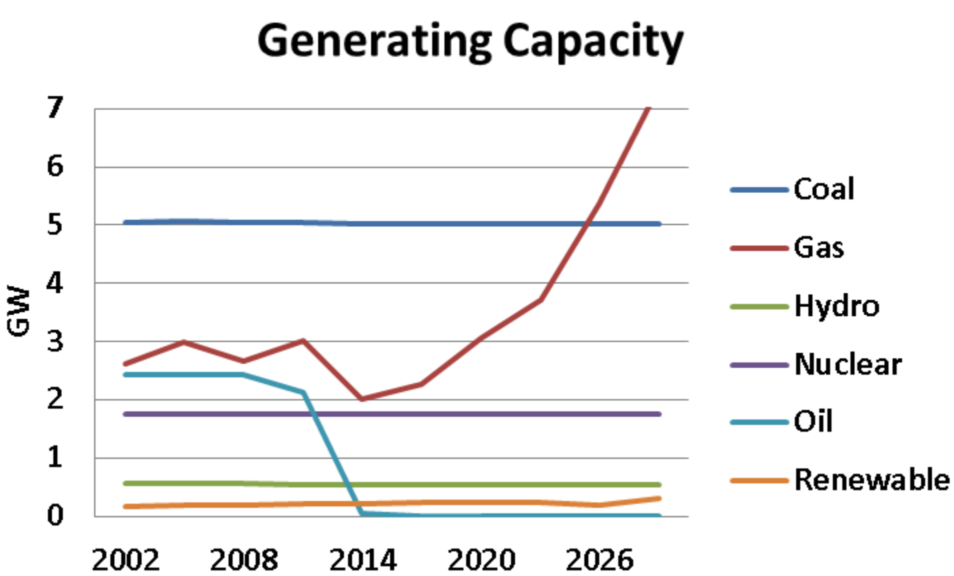


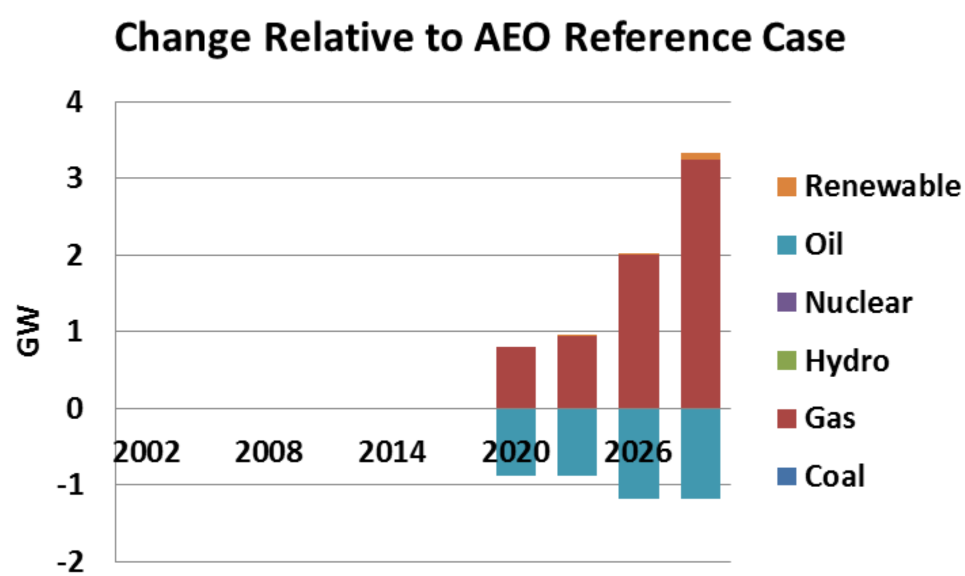
RGGI Scenario Results: Electricity Generation



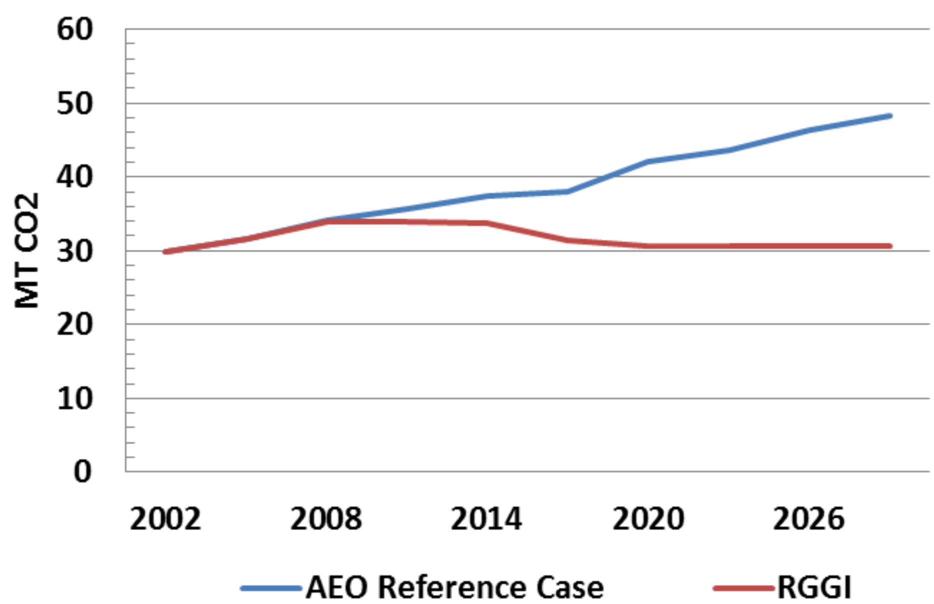


RGGI Scenario Results: Generating Capacity



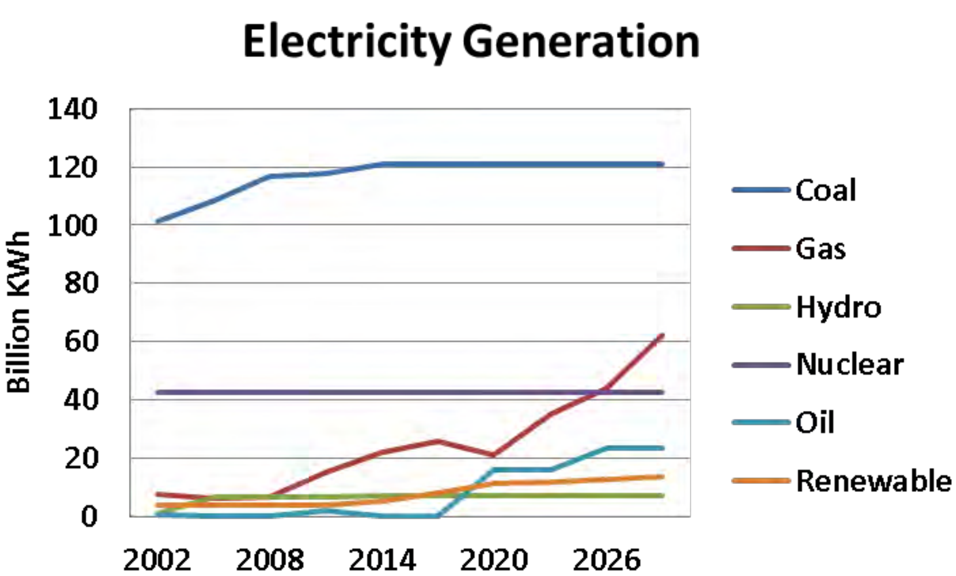


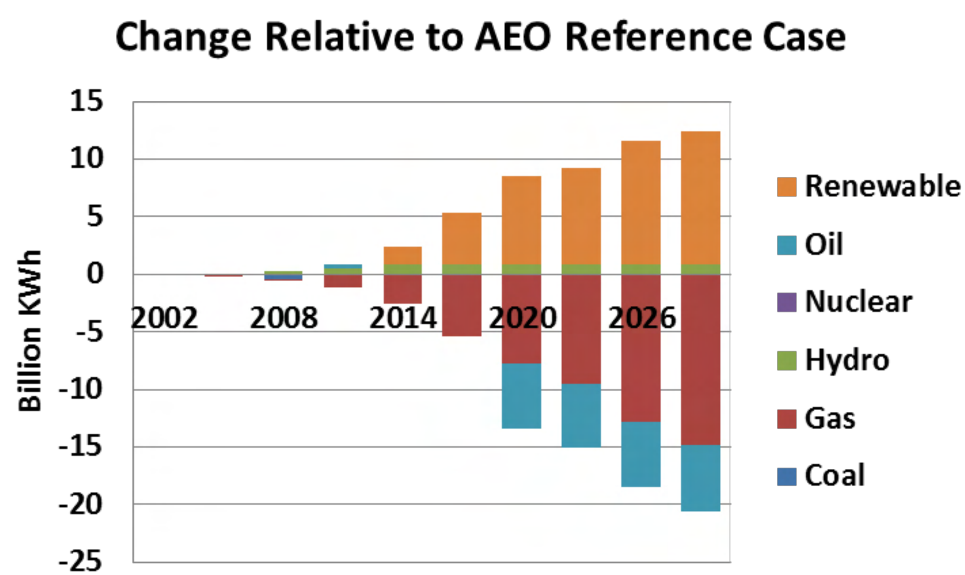
RGGI Scenario Results: Power Sector CO2 Emissions



- Note: see power sector caveats with respect to issues with historical accuracy.
- 2020 reductions represent roughly 11.5 MT or 25% relative to the reference case.

RPS Scenario Results: Electricity Generation





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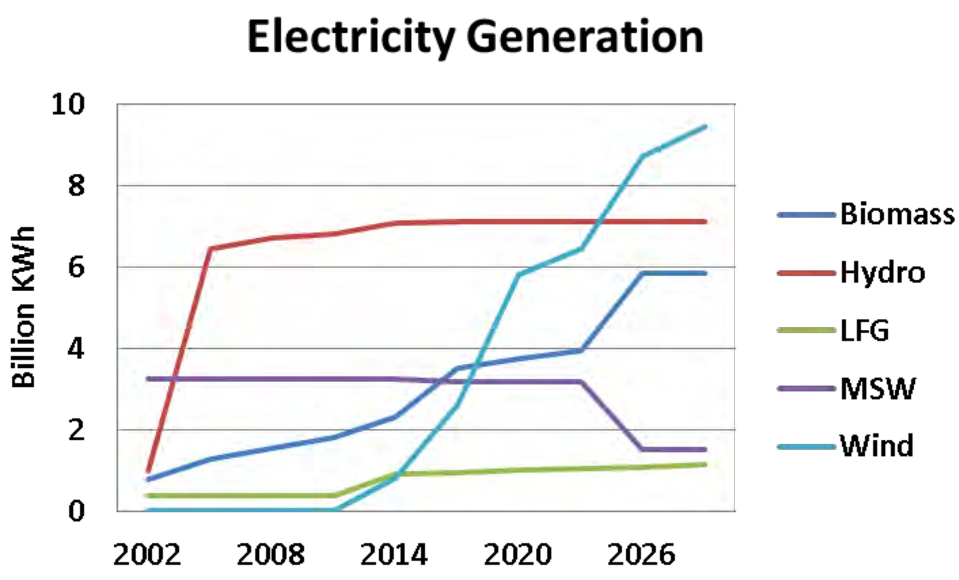
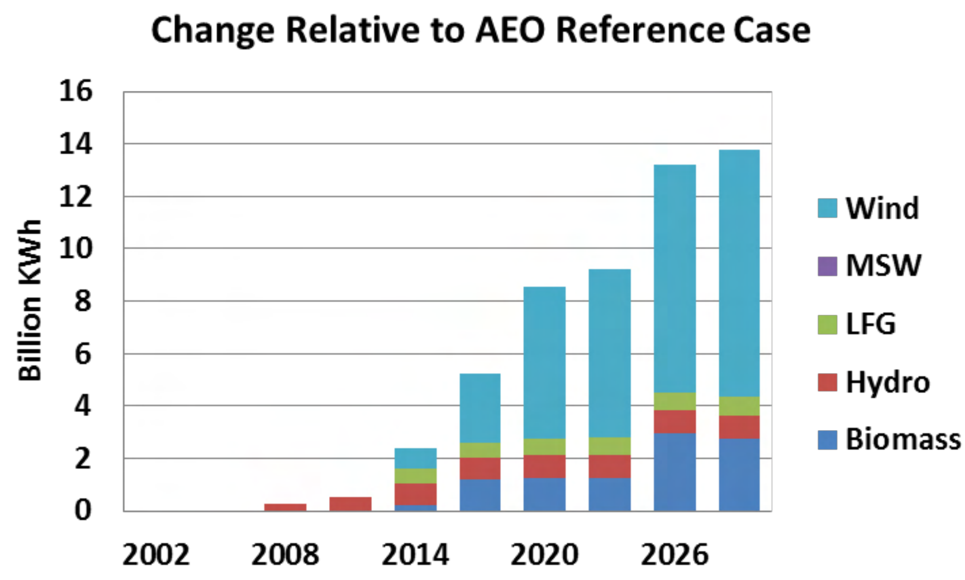
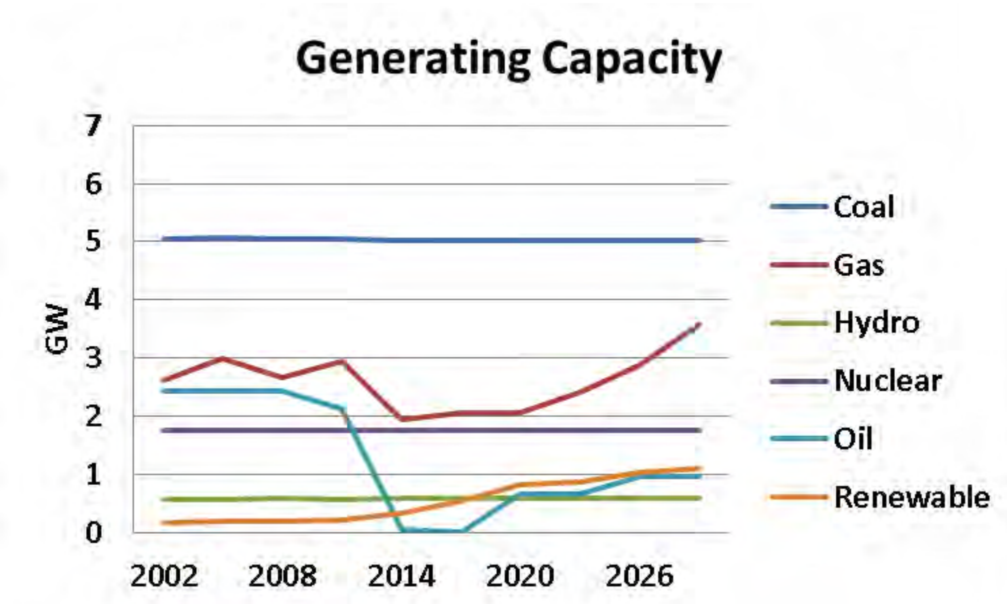
NESCAUM

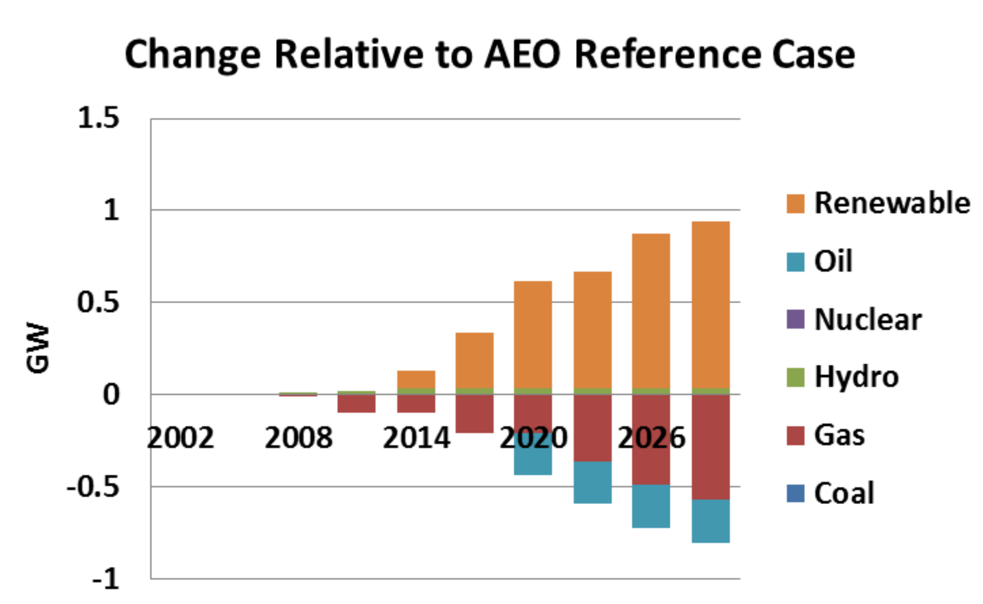
RPS Scenario Results: Renewable Electricity Generation





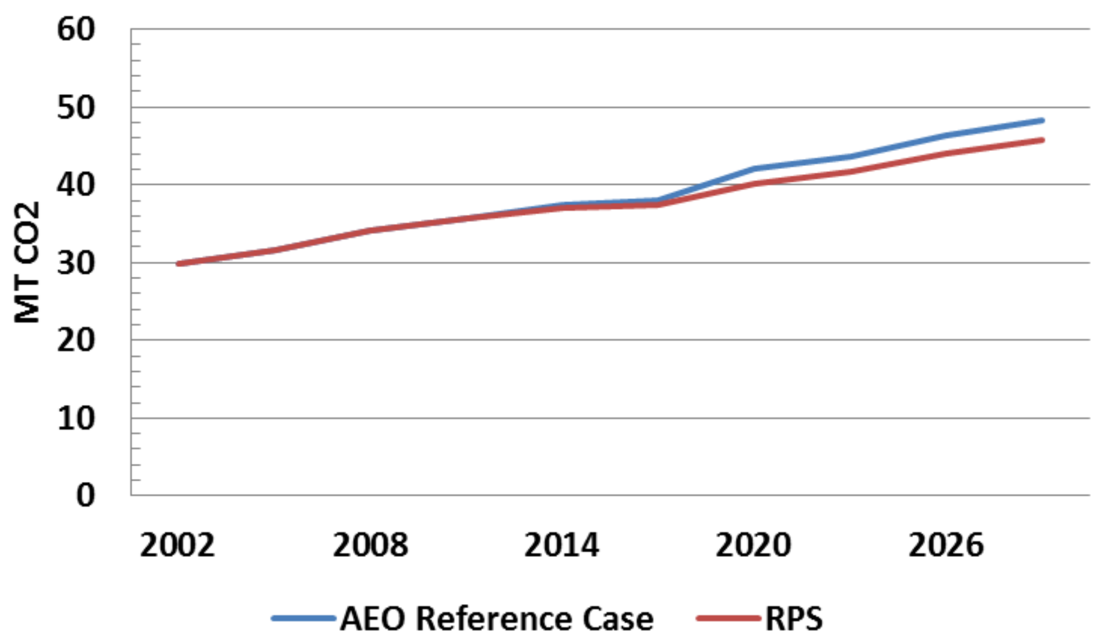
RPS Scenario Results: Generating Capacity





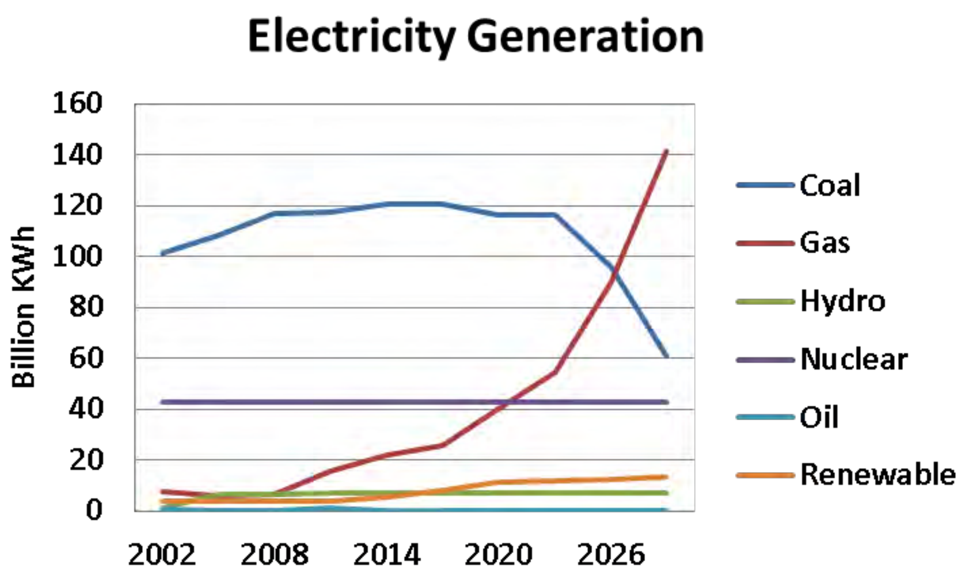
DRAFT PRELIMINARY RESULTS – FOR DELIBERATIVE PURPOSES ONLY.

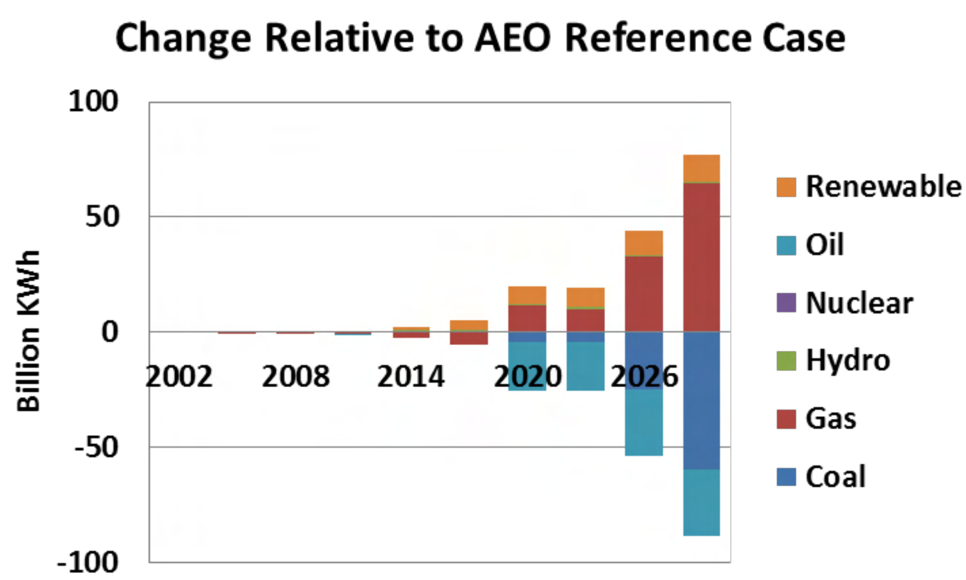
RPS Scenario Results: Power Sector CO2 Emissions



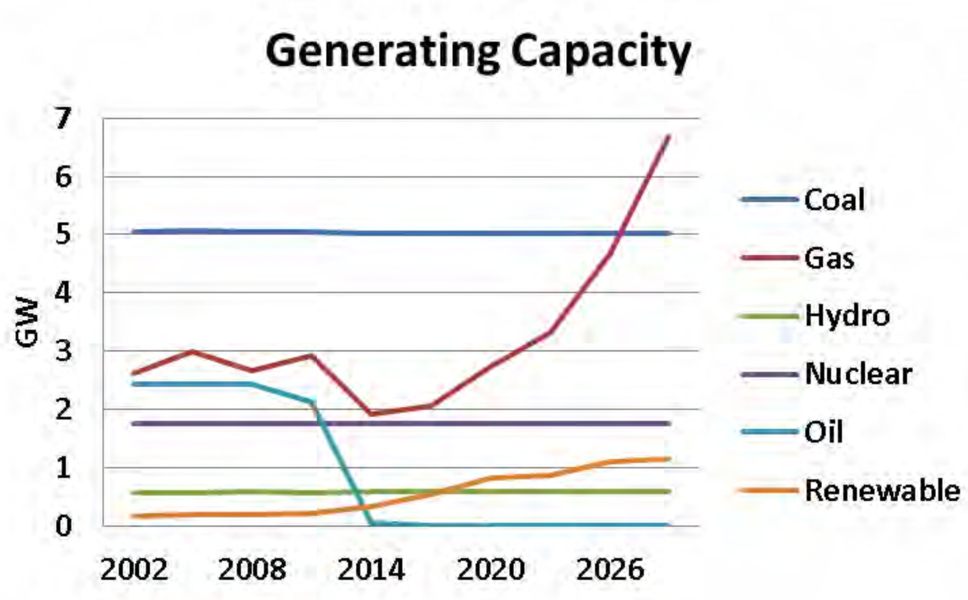
- 10.5 MT of cumulative 2002-2029 CO_2 emissions reductions
- 2.5 MT of reductions in 2029

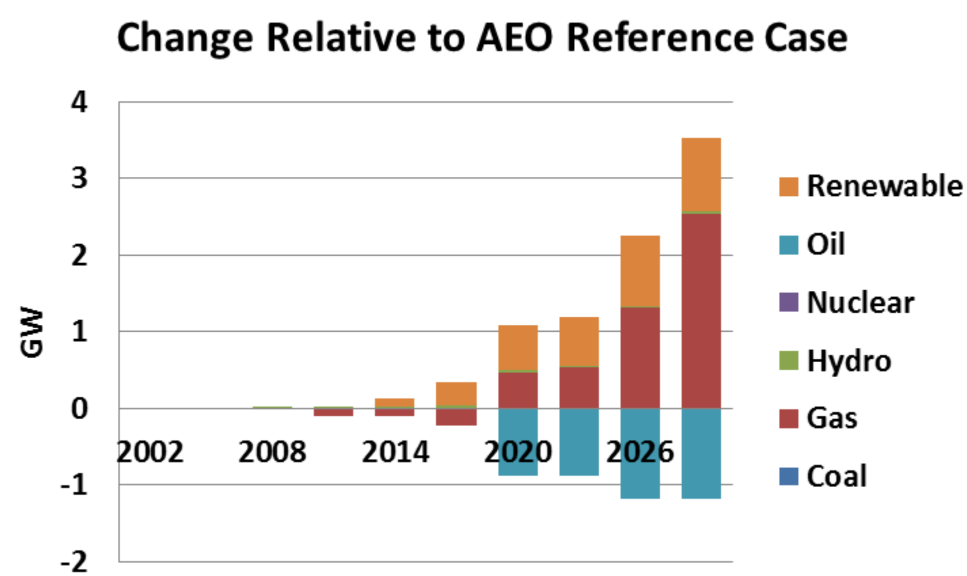
RPS + RGGI Scenario Results: Electricity Generation



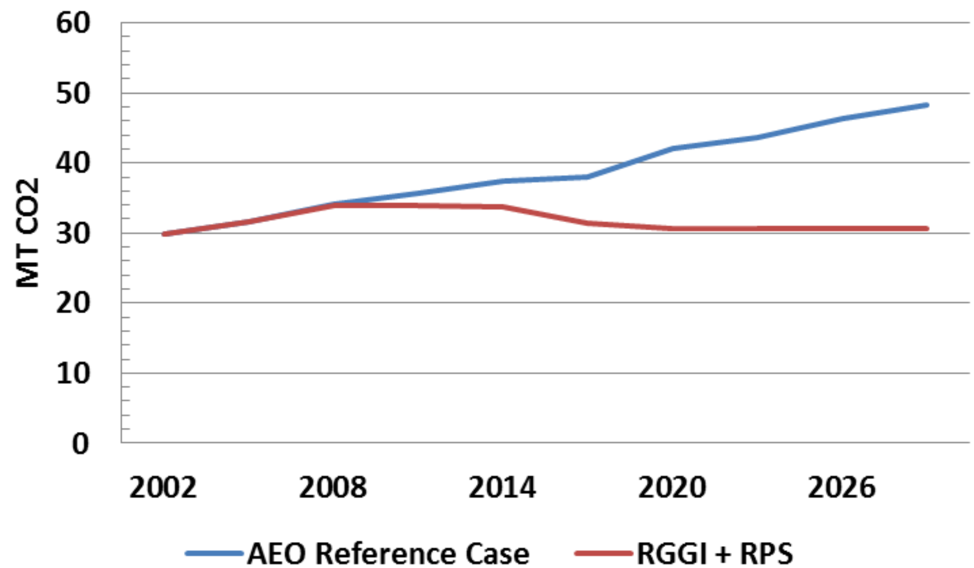


RPS + RGGI Scenario Results: Generating Capacity





RPS + RGGI Scenario Results: Power Sector CO2 Emissions



- 2020 reductions represent roughly 11.5 MT or 25% relative to the reference case or the same as RGGI.
- Because the RPS is at 20% in-state generation, the RGGI reductions mask the GHG benefits of the RPS, but we see a technology shift towards renewables.
- At higher renewable targets we would see additional modeled GHG benefits.

Transportation Sector
Reference Case and Scenarios

Introduction to Transportation Sector Scenarios

- CAFE Standard Options
  - CAFE 1975: 27.5 mpg
  - EISA (2007) federal CAFE update: 37 mpg by 2020. Note: This standard is the current basis for the reference case.
  - EPA/NHTSA CAFE 2011: 54.5 mpg by 2025

- VMT Reduction Strategies
  - NESCAUM aggregated MDOT's estimates of VMT reduction strategies into one overall VMT reduction target

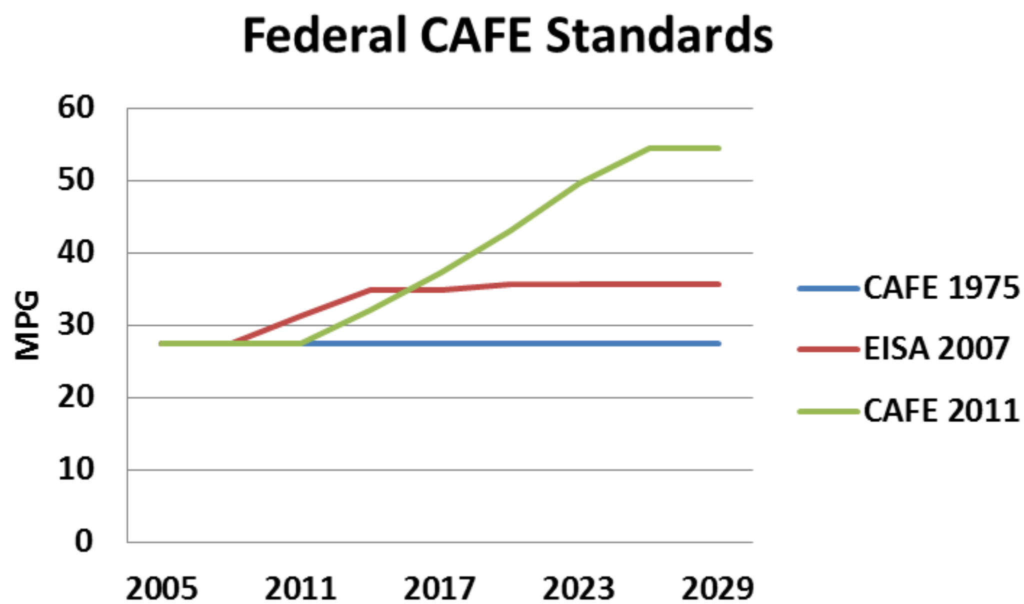
Transportation Sector Inputs

- Lower bound on vehicle deployment by size class

Vehicle Size Class	2005 Share	2029 Share
Small Car	24%	5%
Large Car	28%	5%
Small Truck	27%	8%
Large Truck	11%	5%
Minivan	7%	3%

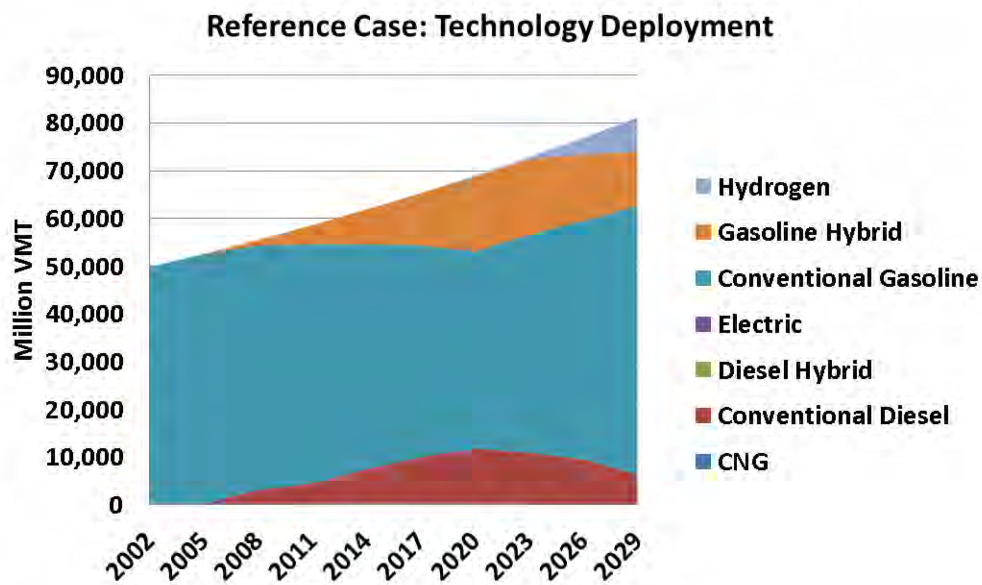
- CNG vehicle penetration is limited to 1% of the LDV fleet because vehicle costs do not account for additional fueling infrastructure.

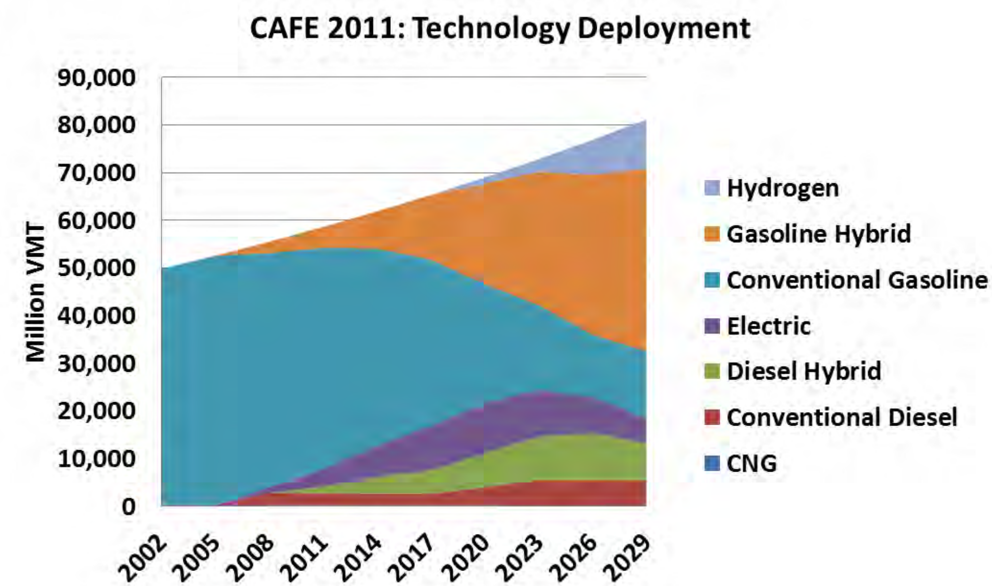
CAFE Standard Scenario Options



- The reference case assumes the EISA CAFE 2007 standard
- The CAFE 2011 scenario achieves 54.5 mpg by 2025

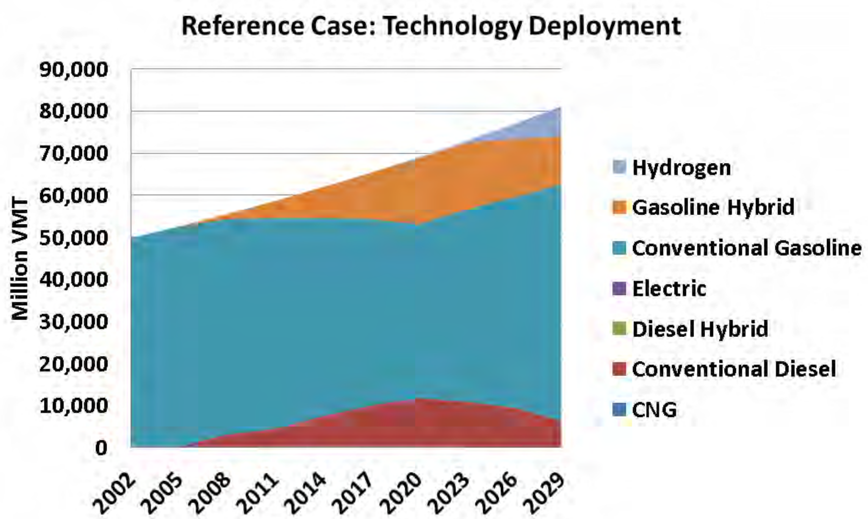
Transportation Reference Case and CAFE 2011 Scenario

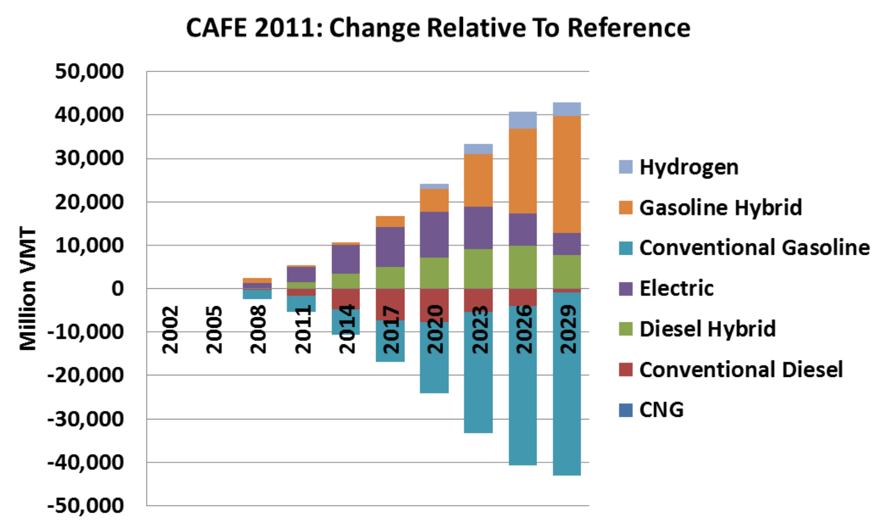




- Note: In the reference case we see a small increase in conventional gasoline vehicles starting in 2023. This will be examined.

Modeled Changes in Vehicle Deployment: CAFE 2011 Scenario v Reference Case





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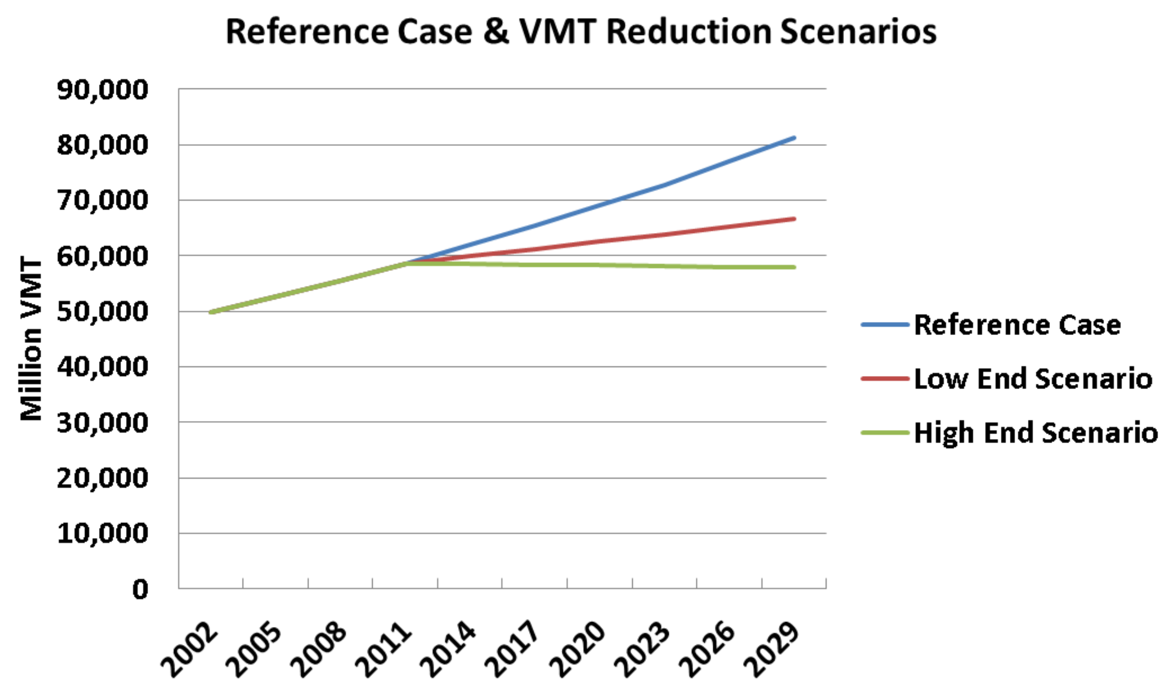
Modeled VMT Reduction Scenarios

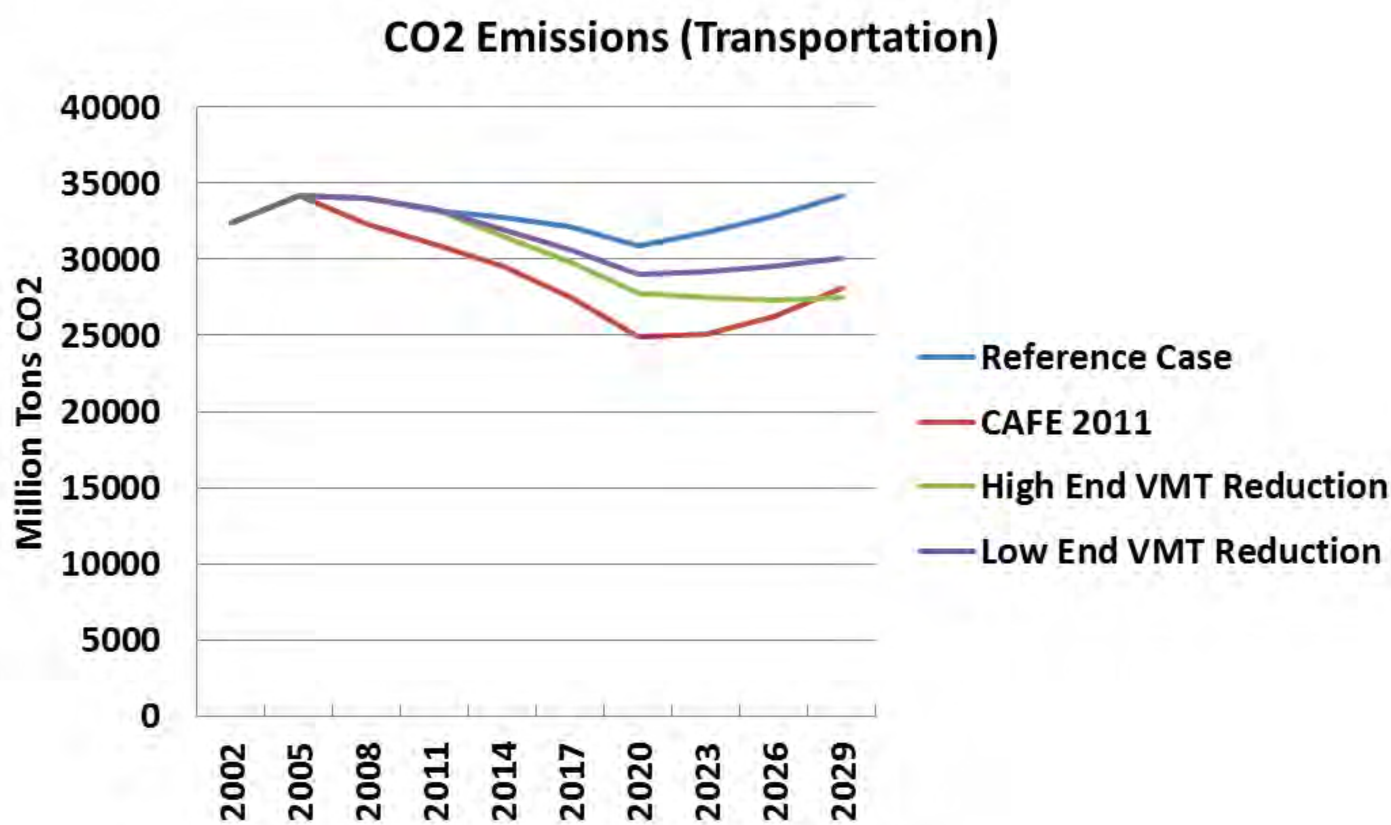
Estimated VMT Reductions by 2020 (MVMT)

	Low End	High End
Funded Strategies		
Terms	897	897
Plans/Pgms	3,558	3,558
Unfunded Strategies		
Intercity Travel		
BWI Access	32	32
IC Pass Rail	74	74
Rail Strategies	23	23
Bike & Pedestrian		
Statewide Trails	61	61
Pedestrian	185	185
Pricing		
Congestion Pricing	279	1,500
VMT Fee	439	2,197
Public Transport	928	2,197
Total	**6,476**	**10,724**



- **VMT reduction estimates are from MDOT's April 2011 DRAFT Climate Action Plan.**
- **The chart extrapolates low and high end 2020 reduction estimates out to 2029.**

Transportation Scenarios: CO2 Emission Results



Million Tons of CO2 Reductions (Transportation)

	2008-2029	2020	2029
CAFE 2011	24,251	5,949	6,042
High End VMT Reduction	23,133	3,168	6,648
Low End VMT Reduction	14,132	1,898	4,101

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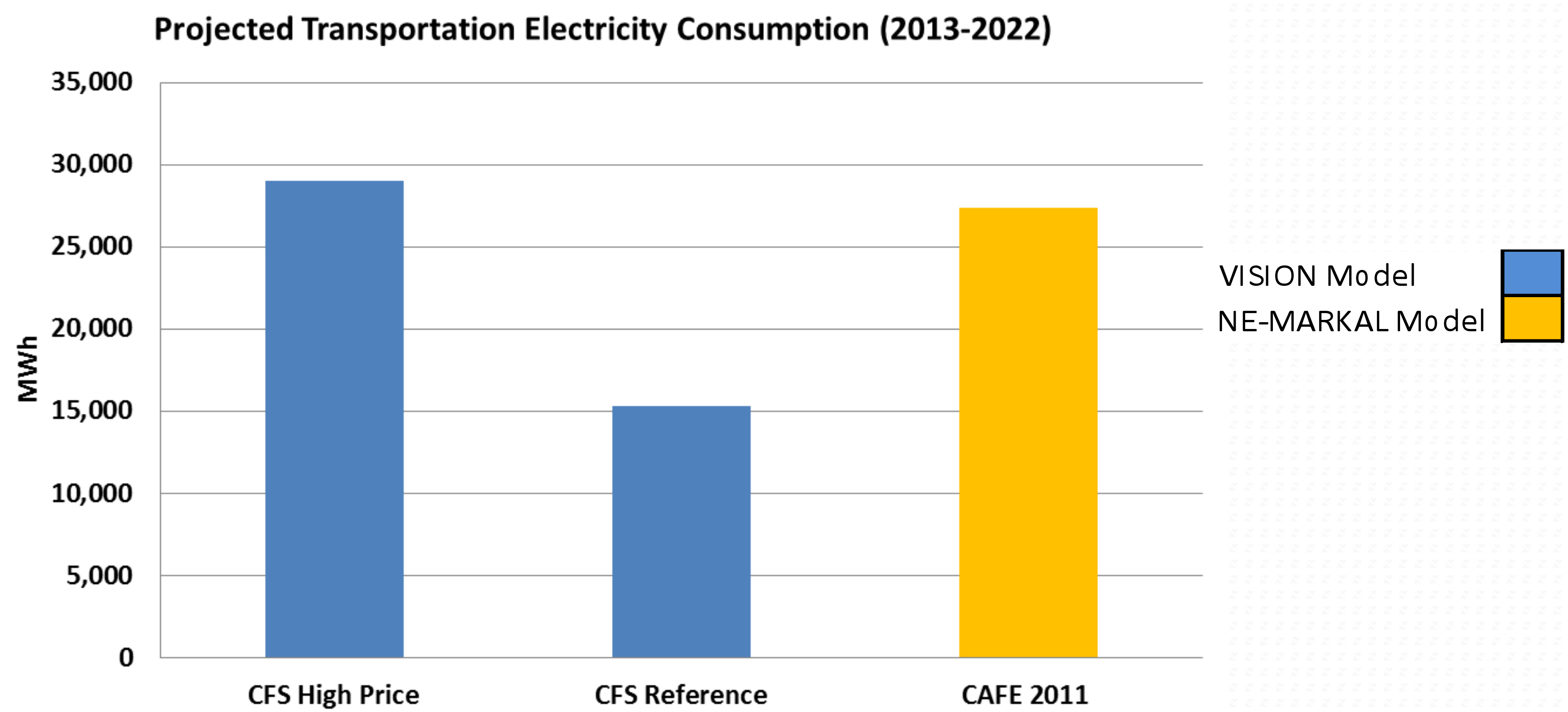
CFS (VISION) vs. CAFE 2011 (NE-MARKAL)



- Compares transportation electricity consumption between two hypothetical CFS VISION scenarios (one assuming high oil prices and one assuming reference oil prices) and a CAFE 2011 NE-MARKAL scenario.
- VISION was used to analyze 3 hypothetical CFS compliance pathways (Biofuels, EV, CNG); only EV is presented here.
- This comparison only suggests that the two programs may be compatible and synergistic from a technology deployment perspective.

Transportation Sector Discussion Topics

- Should this analysis revert to the CAFE 1975 standard?
  - In an earlier work effort, NESCAUM assumed the EISA 2007 update was implemented. This was maintained for these initial results.
- Light-duty technology characterizations
  - Fuel-cell, natural gas and ethanol technology and infrastructure cost updates
- Differences between CFS and CAFE modeling frameworks

Building Sector Reference Case and Scenarios

Introduction to Buildings Sector Scenarios

- Reference Case Summary

- Energy Efficiency (EE) Portfolio Standard
  - Building efficiency increased 20% by 2029 (consistent with EmPower Maryland)

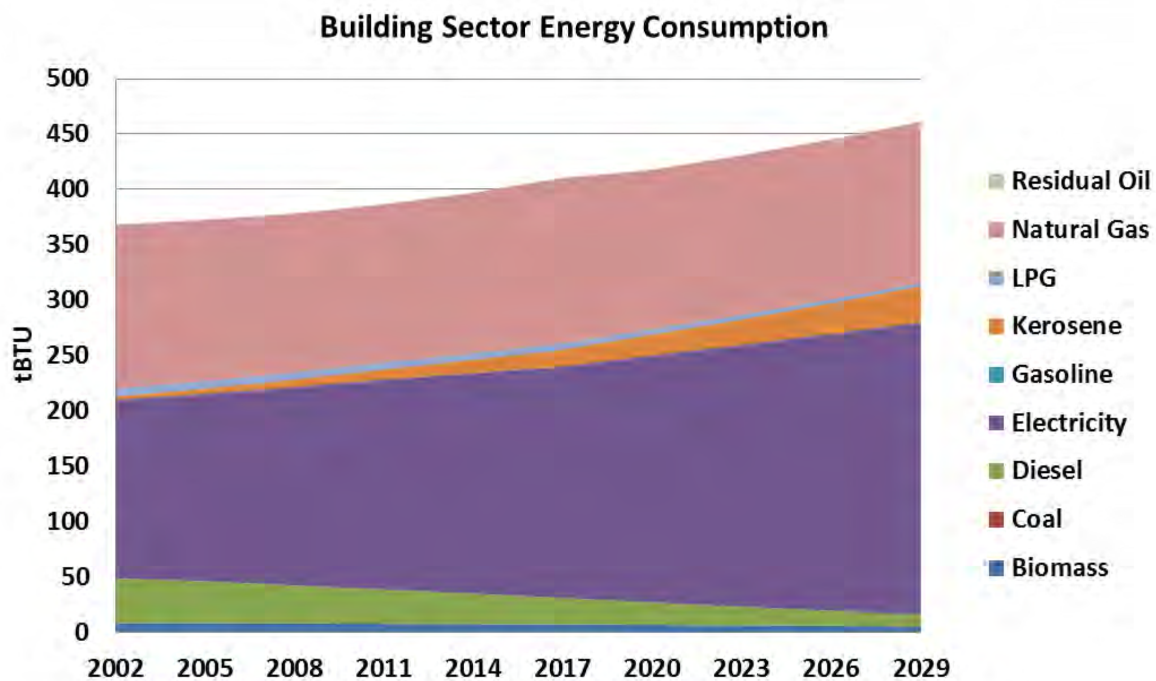
- EE Supply Curves
  - Includes bundles of energy efficiency measures not explicitly modeled in NE-MARKAL

Caveats to Buildings Sector Scenarios

- Several conservation-oriented EE technology bundles were developed based on a study done for New York by Optimal Energy Inc. in 2008.

- The EE potential estimates were scaled using the ratio of Maryland/New York total building energy consumption.

Buildings Sector Reference Case: Energy Consumption



	Average Annual Growth (2008-2029)	Fuel Share 2008
Biomass	-2.0%	2.1%
Coal	-2.7%	0.0%
Diesel	-6.5%	9.0%
Electricity	2.2%	47.3%
Gasoline	-3.6%	0.0%
Kerosene	9.3%	1.8%
LPG	-4.5%	1.7%
Natural Gas	0.1%	37.8%
Residual Oil	-3.5%	0.1%
Total	1.1%	

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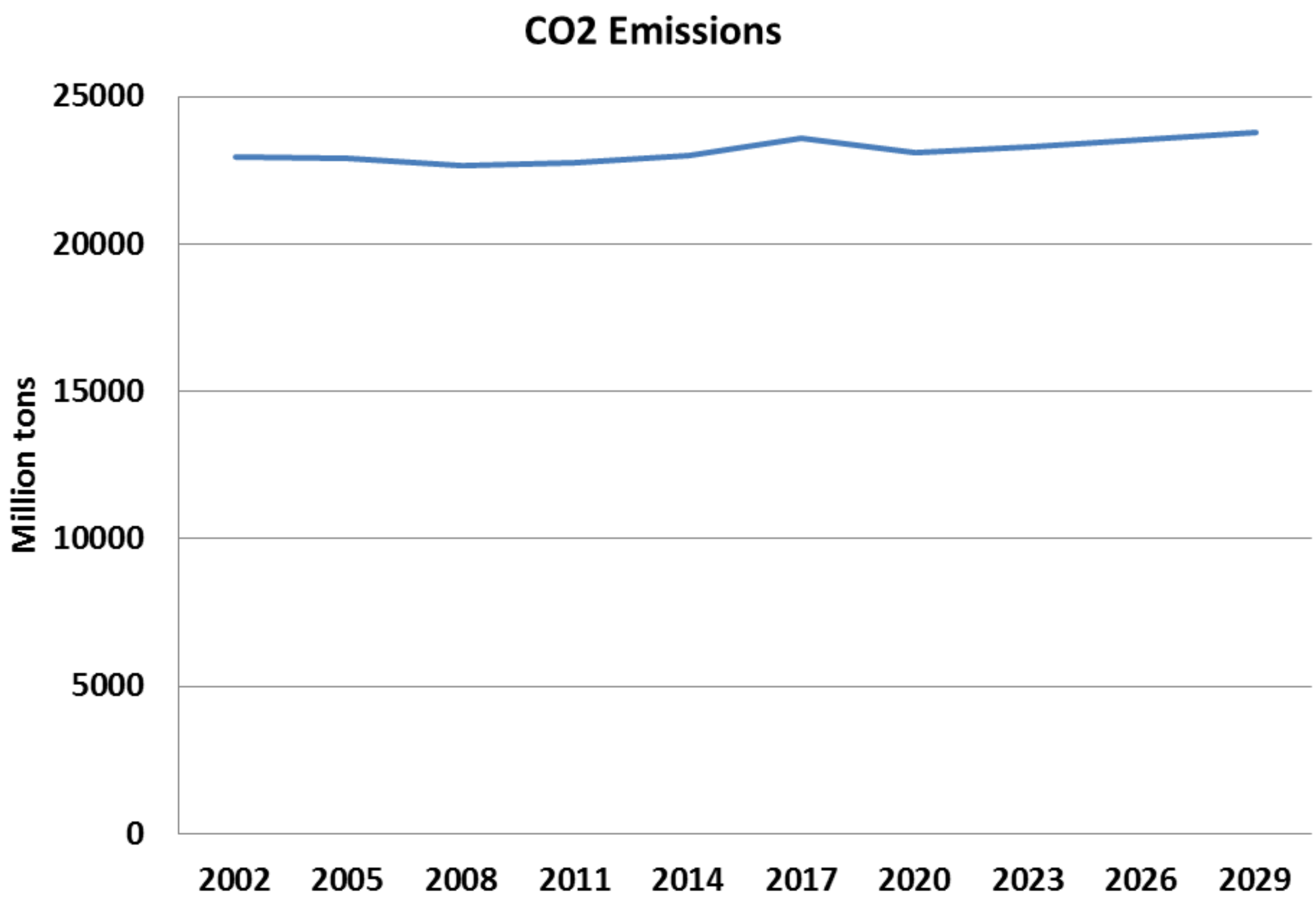
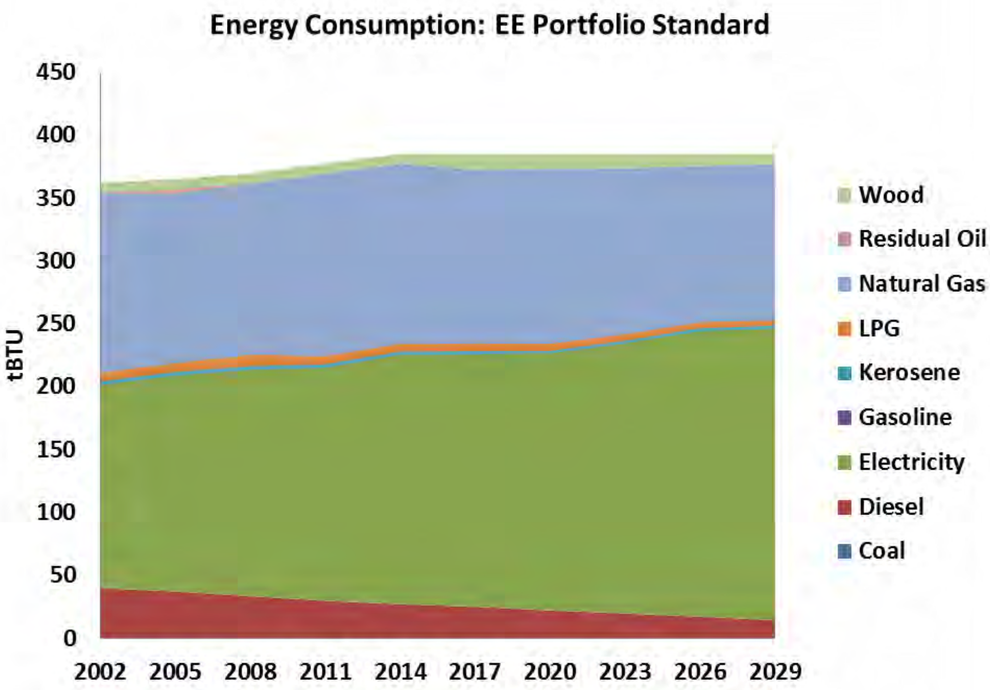
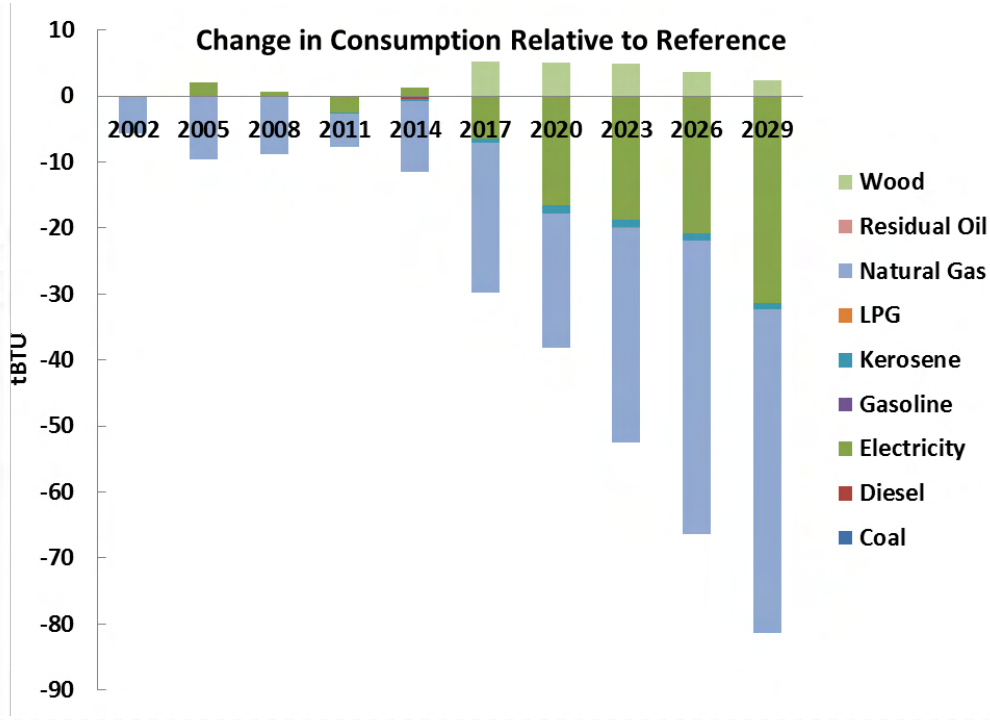
Buildings Sector Reference Case: CO2 Emissions



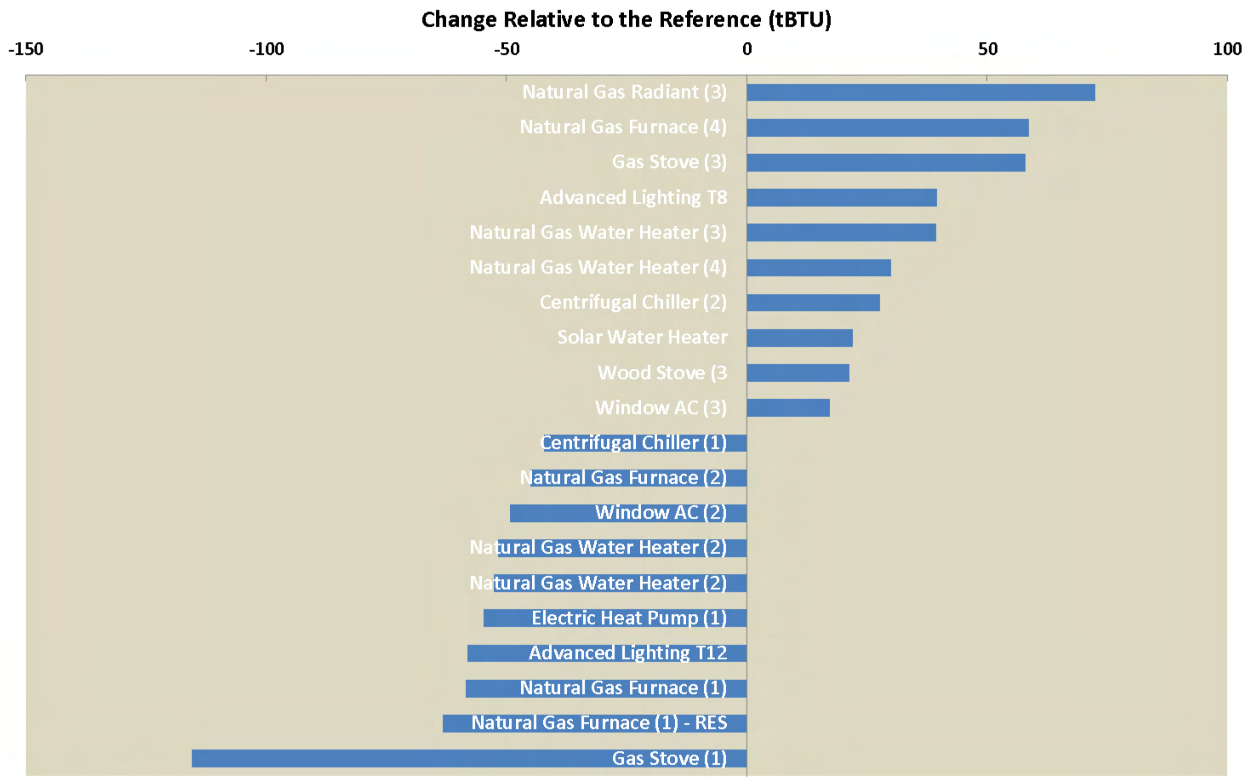
- CO_2 grows at an average annual rate of 0.2% between 2008 and 2029

Energy Efficiency Portfolio Standard Scenario: Energy Consumption



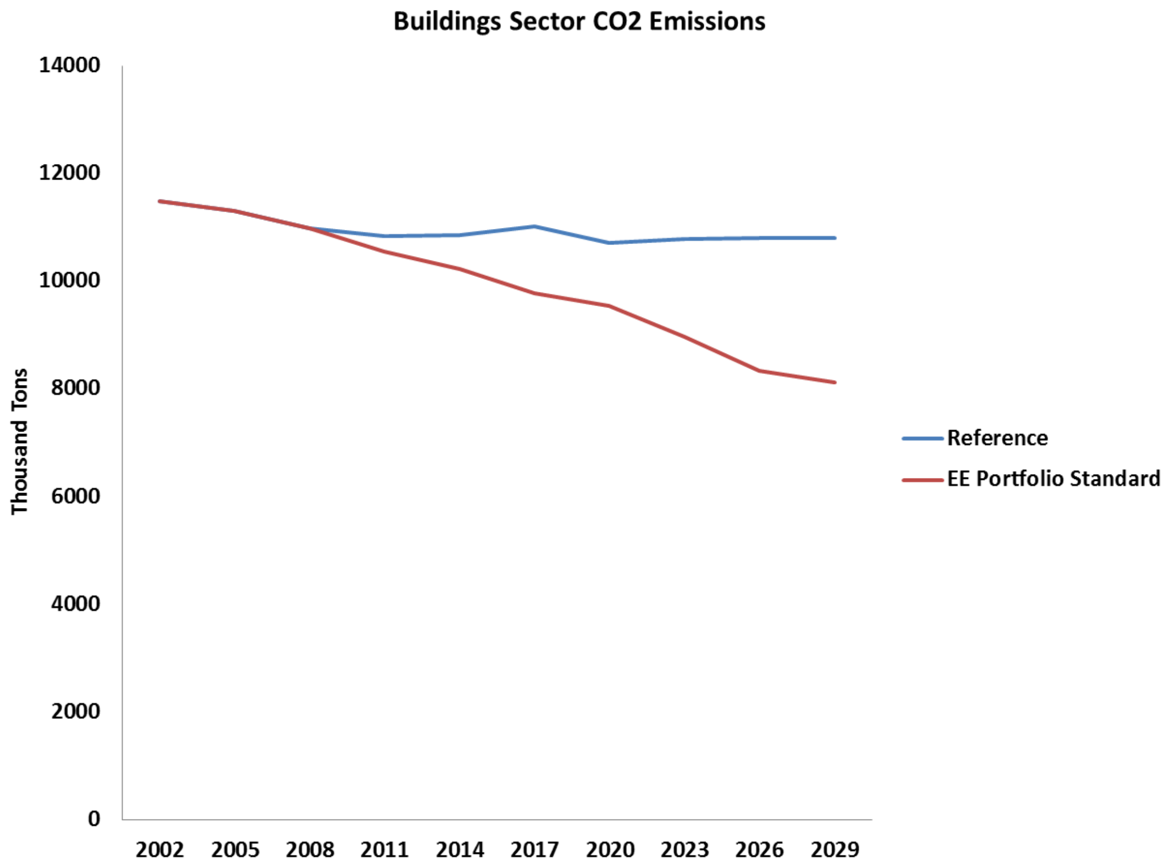


Energy Efficiency Portfolio Standard Scenario: Key Technology Changes



- This shows the modeled top and bottom 10 technologies in terms of change in energy consumption resulting from the EE portfolio standard.
- The parenthetical numbers in the technology names represent the level of energy efficiency; the higher the number, the more efficient the device.
- The energy conservation technologies appear lower on the list of devices used to meet the mandate.

Energy Efficiency Portfolio Standard Scenario: CO2 Emissions



- 2.7 MT of CO_2 reductions in 2029
- 10.3 MT of CO_2 reductions 2011-2029

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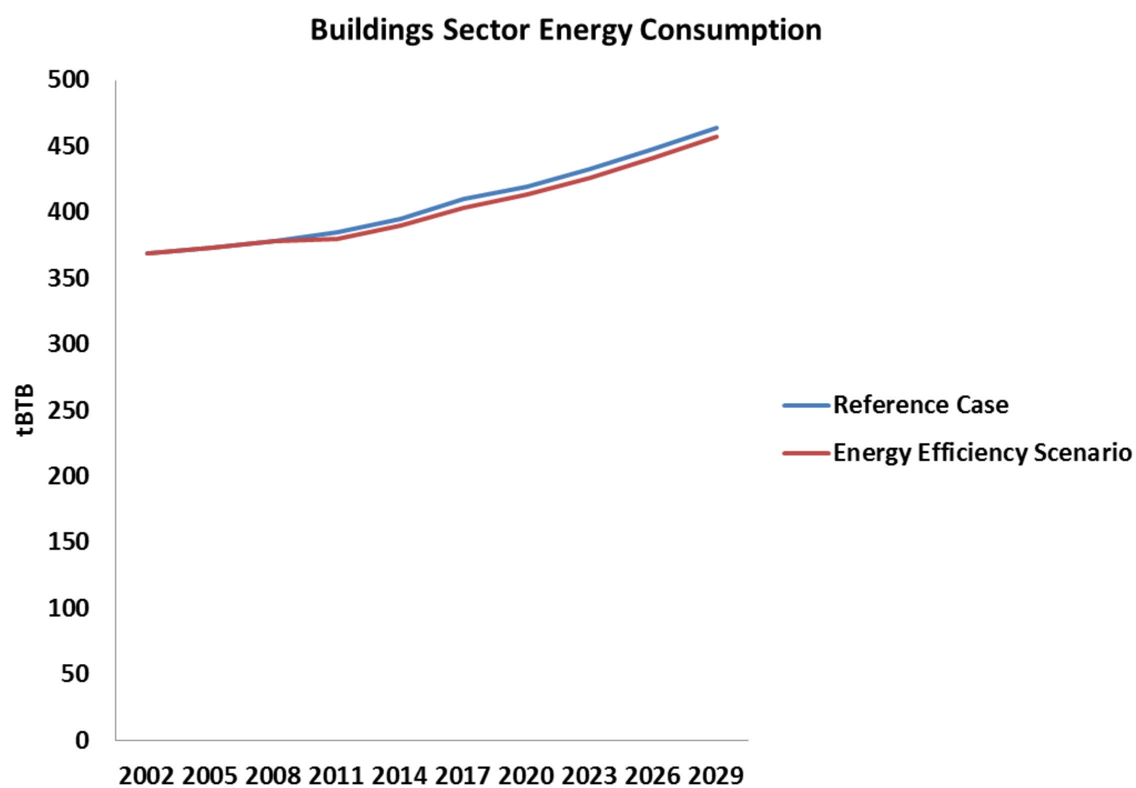
Energy Efficiency Technology Bundles Scenario: Energy Consumption



- With EE tech constrained cumulative energy (2011-2029) consumption is decreased by 1.5%

Buildings Sector Discussion Topics

- We notice that the EE technology bundles do not significantly change building sector energy consumption.
- Scaling the EE potential estimates based on the New York to Maryland building sector energy consumption could be introducing bias.
  - How should we revisit this scaling in future work?

Next Steps

- Review results together.
- Provide feedback on results and possible refinements for next round of modeling.
- Provide feedback on metrics presented and data presentation.
- Set up a follow-up call on the discussion topics.

Questions?

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