The Impacts of the Green Communities Act on the Massachusetts Economy:

A Review of the First Six Years of the Act's Implementation

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About Analysis Group

Analysis Group provides economic, financial, and business strategy consulting to leading law firms, corporations, and government agencies. The firm has more than 600 professionals, with offices in Boston, Chicago, Dallas, Denver, Los Angeles, Menlo Park, New York, San Francisco, Washington, D.C., Montreal, and Beijing.

Analysis Group's energy and environment practice area is distinguished by expertise in economics, finance, market analysis, regulatory issues, and public policy, as well as significant experience in environmental economics and energy infrastructure development. The practice has worked for a wide variety of clients including energy producers, suppliers and consumers; utilities; regulatory commissions and other public agencies; tribal governments; power system operators; foundations; financial institutions; and start-up companies, among others.

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1. EXECUTIVE SUMMARY

Overview: The Massachusetts Green Communities Act

In July 2008, Massachusetts' Governor Deval Patrick signed into law the Green Communities Act (GCA), setting in motion a combination of new policies related to energy supply and use. Having passed with unanimous support of both chambers of the Massachusetts General Court at a time of near record-high energy prices,[1] the GCA represented a significant shift in the state's energy policy, focusing on a number of economic, environmental, and public policy objectives:

- reducing growth in the Commonwealth's electricity demand through economical investments in energy-saving devices;
- expanding the ability of municipalities, residential customers, and businesses to own and benefit from new technologies to produce electricity on their own premises;
- facilitating commercialization of and growth in large-scale energy sources that produce little or no greenhouse gas emissions;
- expanding activity and employment within the state in the advanced energy technology sector; and
- reducing Massachusetts' dependence on and payment for fossil-fuel energy resources outside of the state.

The GCA sought to accomplish these objectives through many actions – all of which were designed to overcome barriers to the adoption of energy efficiency and renewable energy resources: (1) expanding investment in cost-effective energy efficiency (EE) programs carried out by utilities and supported through charges in energy-consumers' monthly bills; (2) allowing municipalities, businesses and residents to take advantage of "net metering programs," in which customers who install renewable generation resources "behind-the-meter" (i.e., on their premises) are paid for any surplus electricity they produce (i.e., "net generation") at close to the retail rate of electricity; (3) requiring electric utilities to enter into long-term contracts for new grid-connected renewable power sources; (4) expanding the state's renewable portfolio standard (RPS) requirements to increase the percentage of retail electricity supply that would need to come from renewable energy sources; and (5) allowing electric utilities to construct and own/operate solar photovoltaic (PV) systems. The GCA also instituted the 'Green Communities program' to support towns pursuing energy conservation and renewable energy generation activities; and provided for utility 'smart meter' pilot programs to investigate the potential consumer and system efficiency benefits of using advanced meters and innovative electricity rate structures.

Since the enactment of the GCA in 2008, there is now a substantial amount of experience with its implementation. There are now actual EE programs, net metering projects, approval of long-term

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[1] Massachusetts city gate prices for natural gas in July 2008 were $15.79 per thousand cubic feet, the record high outside of the period following Hurricane Katrina period when national gas prices spiked. Natural gas prices in 2013 were significantly lower. Average annual electricity prices to customers in Massachusetts at their peak were almost 20 percent higher than they were in 2012. And weekly gasoline prices were also at an all-time high in the summer of 2008. Source: Energy Information Administration data.

contracts for eligible renewable generators, utility construction of solar PV systems, growth in RPS implementation, and widespread participation of cities and towns in the Green Communities program. This implementation has led to significant economic activity in Massachusetts and New England, including investment in renewables and efficiency development, manufacturing, and construction activities, that have already had payoffs and will continue to provide economic benefits in upcoming years. These investments have already had a meaningful impact on the nature and magnitude of power demand and supply in the region, and will continue to do so in the future.

A number of sources fund these GCA programs. EE investment revenues, for example, are collected from electric and natural gas utility ratepayers. Under existing ratemaking policies, all consumers also cover the utility revenues lost as a result of both EE and net metering installations. To the extent the cost of long-term contracts for renewable power differs from the prevailing price of electricity in wholesale markets, the difference is collected from (or refunded to) electric utility customers. And businesses and homeowners that install wind and solar PV and EE measures bear the direct out-of-pocket costs associated with them.

On the other side of the ledger and over a longer term, there are benefits associated with policy implementation. Because wholesale electricity prices are lower and there is increased local investment, the overall Massachusetts economy sees benefits in the form of local jobs, local spending and retention of dollars that would otherwise go toward purchasing fossil fuels produced elsewhere. Additional benefits accrue in the form of lower compliance costs and other benefits associated with programs to address the health, safety and environmental impacts of the air, water, and liquid/solid waste byproducts of energy production.

This Study

Because there are both monetary costs and benefits associated with GCA implementation, a fundamental question is: *on net, how does GCA implementation affect the Massachusetts economy, considering both economic costs and economic benefits*? How has GCA affected the cost to light and heat homes and operate businesses? How do the flow of investments and changes in resource use affect Massachusetts companies' revenues, the number of jobs in the state, and the overall productivity of the Massachusetts economy over time?

In this study we set out to examine the various monetary and economic effects of the GCA. Specifically, we conducted a power-system and macroeconomic analysis of GCA implementation to date, with a focus on programs administered through a period – 2010 through 2015 – that coincides with the implementation period of the first two three-year EE plans established by the GCA and approved by the state. The analysis reviews the direct impacts in that period, as well as the ongoing effects of GCA program actions and investments taken in that time, through a study period ending in 2025. The focus of study is specifically and exclusively on the economic impacts to businesses and households and other organizations within the Commonwealth of Massachusetts.

Importantly, this is not a societal cost/benefit analysis. We did <u>not</u> review the potential mitigation of climate change risks, or the costs or benefits associated with health, safety or environmental impacts (inside or outside Massachusetts). Nor did we review (other than anecdotally) the costs and benefits that accrue to residents and businesses outside Massachusetts – whether in New England or anywhere else in the US or the world. We did not explore any implications for investment conditions in local and regional electric energy markets or structural changes in the Massachusetts economy that could generate second-order market impacts. The scope of this analysis covers the primary impacts of the GCA; while we have made every effort to base our analysis on reasonable and conservative assumptions surrounding current and future electric system infrastructure and costs, we have not attempted to model all future events, policies or investment conditions that might affect new patterns of generation or transmission additions or retirements.[2]

Our analysis is grounded in actual implementation details and real data reflecting the investments carried out or approved to date. Based on those actual investments, inputs reflect costs to consumers and energy market participants, reductions in energy consumed, the generating capacity of new and existing power generating resources, and spending in Massachusetts as a result of these programs. The analysis did not forecast future developments under the GCA beyond the ongoing effects of the investments that have already occurred or that result from action already taken to approve actual renewable energy contracts, to achieve RPS requirements, and to fulfill the energy efficiency programs/plans approved by or filed with regulators.

The analysis compared the implementation of the GCA with a counter-factual ("but for") case where it is assumed the incremental programs, investments and impacts spurred by the GCA had not occurred. We analyzed how the two cases compare from the perspective of money flows and other economic activities within the Massachusetts economy: economic value added, jobs, and tax revenues. The outcomes result from payments by electricity and gas customers to cover the utilities' costs to comply with GCA policies, the costs to those households to install energy efficiency measures or on-site renewable projects, in-state investment in energy efficiency and new generating resources, changes in purchases of energy-related goods and services in the state as compared to other states, and long-term power system impacts of reduced demand and increased generation.

Findings

Our analysis found that the first six years of GCA implementation leads to $1.2 billion (in 2013 net present value dollars) in net economic benefits to Massachusetts, and more than 16,000 jobs.[3] The $1.2 billion also includes state and local tax revenues of roughly $155 million.[4] These represent only the monetary impacts within Massachusetts.[5]

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[2] For example, generation asset retirement decisions are based on what has already been announced and accepted by ISO New England (ISO-NE) as of November 2013. See the Appendix for more details.

[3] This is based on a "public" discount rate of 3 percent. Using a 7 percent "private" discount rate, the benefits are on the order of $0.6 billion. Job numbers equal "job years," reflecting both the number of jobs created and the length of those jobs.

[4] This is based on a "public" discount rate of 3 percent. Using a 7 percent "private" discount rate the tax revenues are on the order of $113 million.

[5] Our study did not attempt to calculate non-monetary costs and benefits inside Massachusetts, or any monetary or non-monetary costs and benefits occurring outside the state.

Table ES-1
Massachusetts Economic Value Added and Jobs Created as a Result of the GCA
(Reflecting Base Case and Alternative Scenarios
Discounted at Private and Public Discount Rates)

Description	3% Discount Rate		7% Discount Rate	
	Value Added*	Jobs**	Value Added*	Jobs**
Base Scenario	$1.17 billion	16,395	$0.63 billion	16,395
High Gas Price (+30%)	$1.80 billion	21,651	$1.13 billion	21,651
Low Gas Price (-30%)	$0.60 billion	11,781	$0.18 billion	11,781

"Economic Value Added" reflects the total economic value added to the economy, which reflects the gross economic output of the area less the cost of the inputs. The reported numbers reflect net present value of economic value added. "*Jobs*" reflect the number of full-time job years over time, and are not discounted.

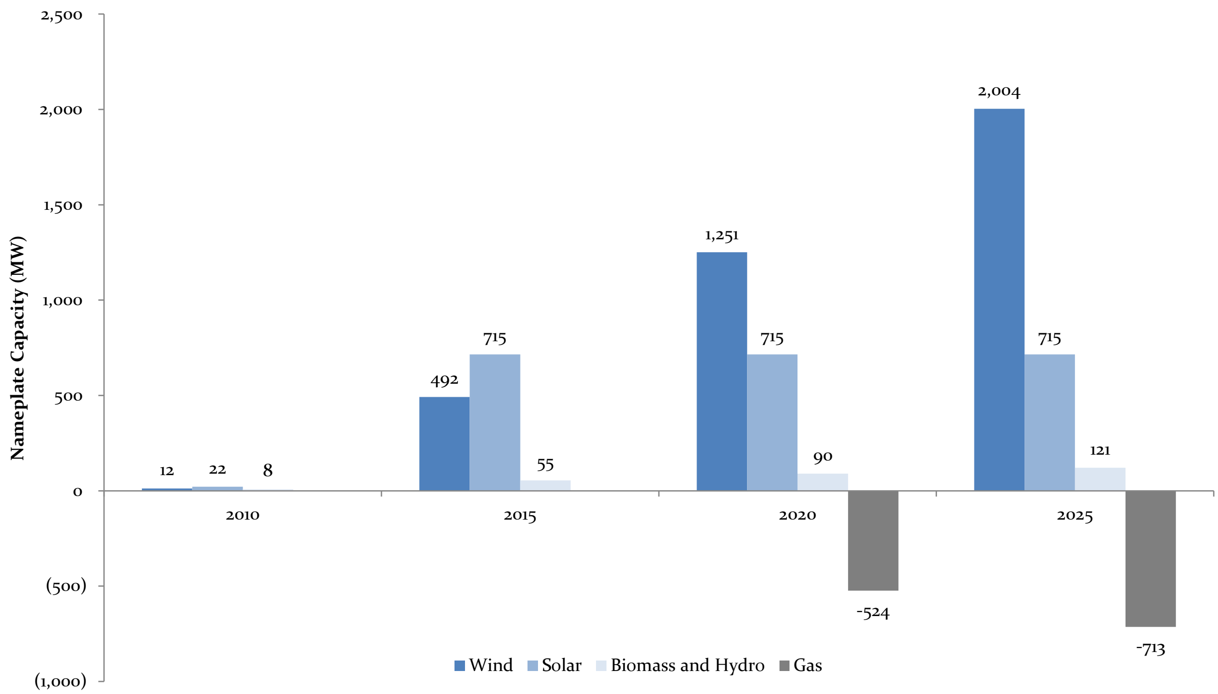
The combination of reduced energy use (from EE investments) and increased renewable generation in the GCA case significantly alters the mix of generating resources in the Northeast power system, compared to the no-GCA case. Specifically, the GCA had already led to and will continue to produce the following types of impacts on the regional power system:

- The addition of roughly 2,800 MW of grid-connected and behind-the-meter renewable resources, with over 1,300 MW located in Massachusetts alone (See Figure ES-1);
- Less need to build new fossil-fired power plants over time, as the reduced demand from EE investments and new renewable installations end up delaying and/or avoiding the addition of roughly 700 MW of new fossil-fueled resources (primarily natural gas-fueled capacity – see Figure ES-1); and
- Reduced power system generation by traditional resources (primarily fossil fuels – coal, oil, and natural gas) in New England's integrated electric system, by nearly 69 terawatt-hours (TWh)[6] from the start of the GCA through 2025. Over the same period renewable (primarily wind and solar) generation increases by roughly 55 TWh.[7] See Figure ES-2.

[6] One TWh is equal to 1 million MWh. In 2012, total power generation in Massachusetts was 36 million MWh, based on Energy Information Administration data.

[7] These changes in resource mix would continue beyond the end of our study period, as installed renewable generation resources would continue to operate for many years beyond 2025.

Figure ES-1
Cumulative Capacity Additions in New England due to GCA
Nameplate Capacity (MW), 2010-2025



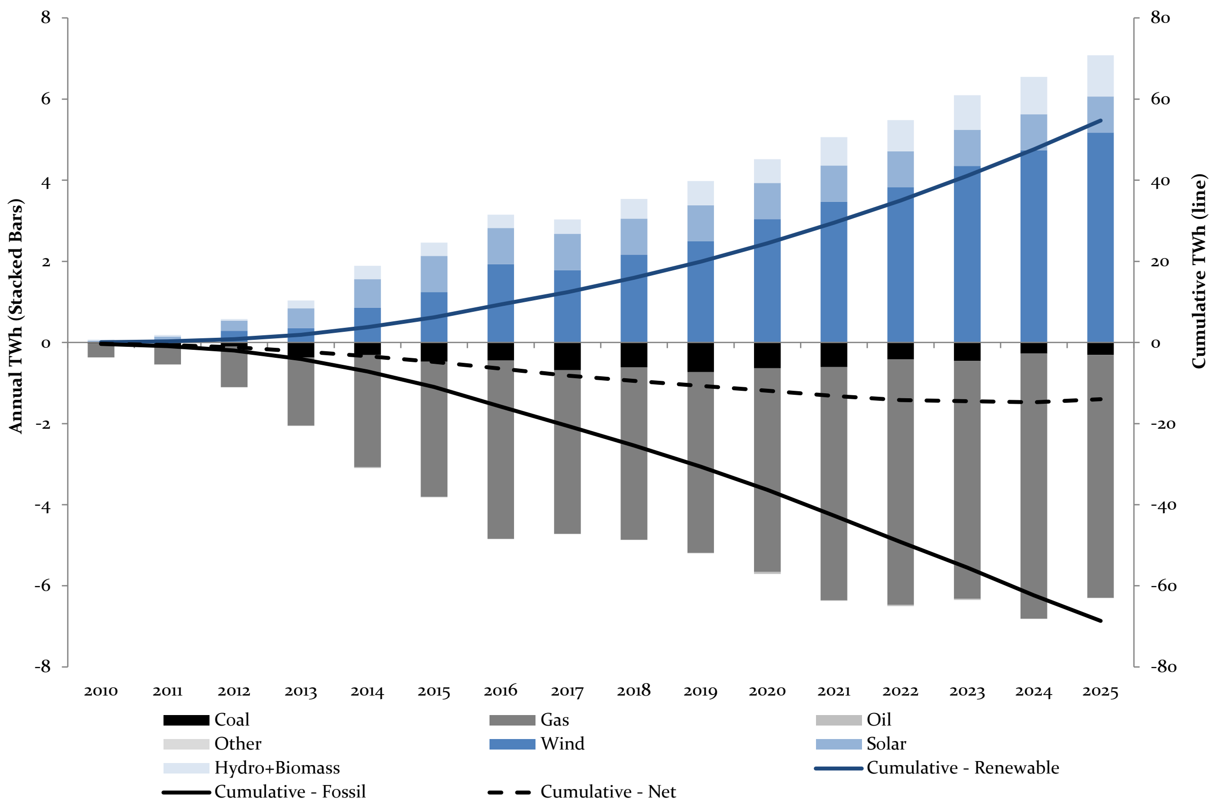
Notes:
[1] Nameplate capacity does not represent the seasonal claimed capability (SCC), which is the basis for capacity market and resource adequacy determinations. For the purposes of this study, additions of nameplate capacity were derated to summer SCC on a technology basis.
[2] Units are added as capacity at the end of the year before they come in-service and generate energy. Thus data shown in 2020 represents units operating in 2021.

The GCA has had and will have a significant impact on electricity demand and power generation within Massachusetts' borders. Specifically:

- Because of lower demand for power, total cumulative energy production to serve Massachusetts consumers (between 2010 and 2025) ends up being 36 TWh[8] lower than it would have been without the GCA.
- Generation from in-state resources is 5.5 TWh lower over the study period in the GCA case (compared to the no-GCA case), equaling a decrease of 0.8 percent. Generation from resources out-of-state decreases by 8.5 TWh.
- With the GCA, cumulative in-state power production from fossil fuels ends up being 33.9 TWh (or 5.8 percent) lower that it would have been, and generation from renewables increases by 28.3 TWh (or 56.6 percent); and
- Revenues to owners of power plants that use traditional fossil fuels (and, by extension, revenues to out-of-state companies that produce and sell of fossil fuels) decrease; revenues to in-state renewable resource owners increase.

[8] This number includes changes in generation from New York and Eastern Canada as well as changes within New England.

Figure ES-2
Cumulative and Annual Differences in New England Generation due to GCA by Resource Type, 2010-2025



__Note__:
[1] Units are added as capacity in the year before they come in-service and generate energy.

Consumers' electricity bills are higher in the near term as a result of GCA implementation. These increases stem from ratepayer funding of utilities' EE programs, paying for renewables to satisfy increased RPS requirements, and paying any above-market costs associated with long-term contracts for renewable power. However, these near-term increases in electricity bills are offset over time by lower wholesale power prices such that overall electricity bill impacts are modest (just under 70 cents per month for average residential customers over the study period).[9] This latter effect is due to two factors: (1) lower overall electricity demand from EE leads to lower overall costs to meet energy needs; and (2) increased renewable generation (plus lower demand) lowers electric energy prices in wholesale power markets.[10] In addition, while the consumers who actually participate in EE and net metering programs incur direct out-of-pocket costs to purchase and install their EE measures and/or PV systems, those particular customers end up with lower electricity bills over time due to their lower energy use or the effects of net metering on their electricity bills.

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[9] This assumes an average residential consumer in Massachusetts uses approximately 625 kWh per month, based on 2012 retail electricity sales and consumer data filed with the Energy Information Administration for Massachusetts.

[10] The latter is often called a "price suppression" effect.

Changes in the electricity supply mix lead to significant changes in pollution for the New England region. We tracked emissions of carbon dioxide (CO_2), mercury (Hg), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). Specifically, over the study period the GCA reduces CO_2 emissions by 31 million metric tons, Hg emissions by 165 lbs, NO_x emissions by 23 million lbs, and SO_2 emissions by 38 million pounds.[11]

Although we did not track quantitatively the impacts on all of them directly, municipalities across the state can – and often do – benefit from both GCA policies and specific GCA Green Communities programs. For example, the City of Boston has received over $1 million to reduce its energy costs through GCA grant money, investing directly in the community for such initiatives as auto igniters for natural gas streetlights, lighting controls at municipal ball fields, and upgrading or installing energy management programs at Copley Library and other branch libraries. The City of Worcester has also received almost $1 million through Green Community grant money and has invested in a residential stretch-code implementation program and outreach campaign.[12]

Finally, because the analysis looks at the value of near-term investments on system costs and benefits over time, we analyzed how sensitive the economic results are to the key driver of electric system pricing in New England – namely the price of natural gas. Massachusetts' electricity prices are highly influenced by the underlying price of natural gas used for power generation in the region. Also, natural gas is used to heat buildings, whose future energy use in influenced by EE measures supported by the GCA. Therefore, our estimates of long-term impacts are sensitive to assumptions about natural gas prices (which affects the value of programs that lower gas consumption for direct use and for electricity generation). Our base case assumed a natural gas price consistent with the outlook in current natural gas markets. The two sensitivities assumed a higher and lower gas price forecast: If gas prices were 30 percent higher than assumed in the base case, benefits of GCA would increase to almost $1.8 billion, with almost 22 thousand total jobs added.[13] If gas prices were 30 percent lower than assumed in the base case, then total benefits would be reduced to $0.6 billion.[14]

In short, implementation of the GCA over the first six years has led to economic benefits to the Massachusetts economy from the perspectives of adding economic value and creating jobs, while also helping achieve the energy and environmental policy objectives behind the GCA.

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[11] Note that three of these pollutants are controlled across most of the states included in the power systems of the Northeast U.S. through regional or nation-wide caps on emissions, with full trading of allocated or purchased allowances. Consequently, estimated "reductions" in emissions modeled in the study may over time lead to reduced costs of compliance (compared to the no-GCA case) rather than an absolute reduction in the number of tons emitted.

[12] A "stretch-code" is a local-option building code that sets a standard of 20 percent to 30 percent more energy efficient than the Commonwealth's recently adopted statewide code. Green Communities Division, Massachusetts Department of Energy Resources.

[13] This is based on a 3% discount rate. At 7% the number is approximately $1.1 billion.

[14] This is based on a 3% discount rate. At 7% the number is approximately $0.2 billion.

2. INTRODUCTION TO THE GCA AND SUMMARY OF ITS IMPACTS

Background: The Green Communities Act

In July 2008, Massachusetts' Governor Deval Patrick signed into law the Green Communities Act (GCA), setting in motion a combination of new policies related to energy supply and use. Having passed with unanimous support of both chambers of the Massachusetts General Court at a time of near record-high energy prices,[15] the GCA represented a significant shift in the state's energy policy, focusing on a number of economic, environmental, and public policy objectives:

- reducing growth in the Commonwealth's electricity demand through economical investments in energy-saving devices;
- expanding the ability of municipalities, residential customers, and businesses to own and benefit from new technologies to produce electricity on their own premises;
- facilitating commercialization of and growth in large-scale energy sources that produce little or no greenhouse gas emissions;
- expanding activity and employment within the state in the advanced energy technology sector; and
- reducing Massachusetts' dependence on and payment for fossil-fuel energy resources outside of the state.

The GCA sought to accomplish these objectives through many actions – all of which were designed to overcome barriers to the adoption of energy efficiency and renewable energy resources: (1) expanding investment in cost-effective energy efficiency (EE) programs carried out by utilities and supported through charges in energy-consumers monthly bills; (2) allowing municipalities, businesses and residents to take advantage of "net metering programs," in which customers who install renewable generation resources "behind-the-meter" (i.e., on their premises) are paid for any surplus electricity they produce (i.e., "net generation") at nearly the full retail rate of electricity; (3) requiring electric utilities to enter into long-term contracts for new grid-connected renewable power sources; (4) expanding the state's renewable portfolio standard (RPS) requirements to increase the percentage of retail electricity supply that would need to come from renewable energy sources; and (5) allowing electric utilities to construct and own/operate solar photovoltaic (PV) systems. The GCA also instituted the 'Green Communities program' to support towns pursuing energy conservation and renewable energy generation activities, and provided for utility 'smart meter' pilot programs to investigate the potential consumer and system efficiency benefits of using advanced metering and innovative electricity rate structures.

[15] Massachusetts city gate prices for natural gas in July 2008 were $15.79 per thousand cubic feet, the record high outside of the period following Hurricane Katrina period when national gas prices spiked. Natural gas prices in 2013 were significantly lower. Average annual electricity prices to customers in Massachusetts at their peak were almost 20 percent higher than they were in 2012. And weekly gasoline prices were also at an all-time high in the summer of 2008. Source: Energy Information Administration data.

Since the enactment of the GCA in 2008, there is now a substantial amount of experience with its implementation. There are now actual EE programs, net metering projects, approval of long-term contracts for eligible renewable generators, utility construction of solar PV systems, growth in RPS implementation, and widespread participation of cities and towns in the Green Communities program. This implementation has led to significant economic activity in Massachusetts and New England, including investment in renewables and efficiency development, manufacturing, and construction activities, that have already had payoffs and will continue to provide economic benefits in upcoming years. These investments have already had a meaningful impact on the nature and magnitude of power demand and supply in the region, and will continue to do so in the future. It also has required the assessment of additional charges to electric and gas ratepayers to fund the various GCA programs.

GCA Program Summary

Energy Efficiency

Under the GCA, electric and natural gas distribution companies have increased their investment in EE, consistent with the GCA goal of achieving all EE that is cost effective or cheaper than supply. Planning for this new EE investment has taken place within a new process, supported by an Energy Efficiency Advisory Council (EEAC)[16] established by the GCA. The EEAC process develops three-year EE plans on an integrated state and cross-industry basis (i.e., natural gas and electric industries). Individual utilities then develop company-specific plans, which are submitted to the Massachusetts Department of Public Utilities (DPU) for review and approval.

The first three-year plans were approved by the DPU in December 2009 for the period 2010-2012. The second three-year plans were approved by DPU in December 2012 for the period 2013-2015. Total annual budgets for the EE plans of electric utilities were approximately $200 million in 2009, prior to the first three-year plans taking effect. Total budgets since then have risen (or will rise) from approximately $250 million in 2010, to almost $550 million in 2015. For the gas utilities, EE spending increases from approximately $65 million in 2010 to just under $185 million in 2015.[17]

Once fully implemented by the beginning of 2016, EE measures and programs funded through the first two three-year plans under the GCA will save consumers a total of 3,617 GWh per year, and will reduce the state's peak summer electricity demand by 614 MW, or five percent of total peak load. On the gas side, incremental GCA EE programs and measures (above and beyond what was in place as of 2009) will reduce annual gas consumption by over 4.6 million MMBtu by the start of

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[16] The EEAC is a multi-party deliberative council involving a cross section of stakeholders from various sectors, assembled to develop three-year plans through a process overseen by the Massachusetts Department of Energy Resources (DOER).

[17] Program budgets are reported in nominal dollars. See the Massachusetts Energy Efficiency Advisory Council, available at: http://www.ma-eeac.org/Three%20Year%20Plans.html

2016, saving consumers approximately $25 million per year in heating, cooking, and processing costs.[18]

GCA electric EE programs, while funded at a cost to consumers, also save consumers money in two ways. First, the level of EE funded through the GCA EE provision is significant enough to lower regional power demand, thereby lowering the price of power in wholesale markets. Those price reductions affect prices paid by all consumers in Massachusetts and across New England, not just those who install energy efficiency measures in their homes or buildings (i.e., the EE program participants). Second, those consumers that do participate in the EE program (and typically make some level of investment to install EE measures) get the additional benefit of consuming less electricity and therefore save on their monthly electricity bills.

Net Metering

The GCA required that the DPU expand its net-metering regulations affecting customers with on-site energy resources that are eligible for "behind-the-meter" (BTM) net-metering services. Under net-metering policies and tariffs, customers who install eligible on-site generation can use that power to satisfy their own demand, provide the utility with any excess power generated above their own requirements in any hour, and use that excess power to offset their purchases of power from the utility at times when the on-site generation does not cover on-site electricity use.

Under the GCA, eligible resources include any type of generating facility as long as it is smaller than 60 kilowatts ("kW"), or if the generating facility uses wind, solar, anaerobic digestion, or renewable energy at a farm, it can be up to 2 MW in size.[19] In addition to expanding the size of eligible facilities, the GCA had the effect of increasing the price paid for excess electricity generated by eligible on-site facilities: whereas previously such supply would be paid the wholesale price of power, after the GCA, net-metering customers would be compensated at nearly the full retail rate of electricity. With additional revisions to the net-metering law passed in 2010 and 2012, the overall quantity of on-site resources allowed to subscribe for net metering is capped at six percent of the utilities' highest historical peak load, with half of this (three percent) reserved for "public" customers (e.g., cities and towns).

By 2010 the DPU had approved net-metering tariffs for all utilities, and utility customers could begin taking service under such tariffs. Customers could thereafter sign up for service under net-metering tariffs until the total MW of subscribed resources were to hit the legislative caps. By the end of 2013 total subscriptions (both interconnected and reserved or pending allocations) under the net-metering tariffs equaled approximately 77 percent of cap levels. At current participation rates, and given the level of projects in the net-metering queues, the current net-metering caps will be fully subscribed with operating projects by the end of 2015. Once fully subscribed, total net-metering resources will likely include approximately 626 MW of solar PV, and 37 MW of wind resources.

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[18] This assumes an annual average cost of natural gas delivered to Massachusetts of $5.54/MMBtu in 2015. Savings to consumers are expected to increase each year for the life of the installed measures as forecasts for natural gas prices predict an increase over time.

[19] Prior to the GCA net metering was only allowed for generation less than 60 kW in size.

By increasing BTM on-site generation, the GCA net-metering program also reduces the need for generation and transmission of electricity at the wholesale level, and thereby contributes to lowering regional wholesale costs. Further, participants in the program end up substantially reducing their monthly cost of electric service because their on-site power supply either enables them to avoid paying some or all retail charges for electricity (e.g., costs associated with local distribution service) over a given month, and/or allows them to generate excess energy that can be profitably shared[20] with others within the same utility's service territory.

All electricity customers end up picking up the costs associated with utility revenues foregone by net-metering customers. In other words, the revenues that net-metering customers avoid through the net-metering policies are effectively recouped over time by the utility through ratemaking mechanisms (net metering reconciliation and/or revenue decoupling).

Grid-Scale Renewable Power: Utility-Owned Solar and Long Term Contracts

The GCA contains a number of provisions to foster the development of new grid-scale renewable power projects throughout the region. Section 58 of the GCA provides that an electric or distribution company may construct, own and operate generating facilities producing solar energy, and may seek cost recovery pre-approval from the DPU to recover costs associated with such facilities. Each utility may construct up to 50 MW of solar PV under this section of the Act. Based on actions to date, it is anticipated that at least 23 MW of solar facilities have or will have been constructed or contracted through the end of 2014.

In addition to ownership options, Section 83 of the GCA requires that the electric utilities solicit for the purchase of eligible new renewable resource output through long-term contracts for the purchase of energy, capacity, and/or renewable energy credits (RECs). To date, National Grid and NSTAR (now Northeast Utilities) have entered into contracts under Section 83 for approximately three quarters of the output of the proposed Cape Wind project, and the utilities have been through two rounds of solicitations for other resources. The first solicitations initiated in July 2009 procured approximately 510 MW of wind resources from sites in Maine, New Hampshire, and Massachusetts.[21] Similarly, the utilities recently completed a joint solicitation, and have requested that the DPU authorize them to acquire an additional 565 MW of generation, located in Maine and New Hampshire. Consequently, as a result of Section 83 procurements to date, approximately 1,070 MW of new wind-powered generation is expected to be built across New England.

Generally speaking, these contracts are structured to have the utilities take title to energy, capacity and/or RECs, and resell the contract quantities into wholesale markets. Customers are then credited or debited the amounts by which such sales net revenues above or below contract

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[20] The excess electric power is not actually shared with others in a physical sense. The excess generation over the course of a given month is metered, and that amount can be used as a credit against other customers' bills, provided the appropriate billing information is provided to the utility by the customer with eligible net metering facilities installed on their premises.

[21] Unitil also contracted for just over 2 MW of hydroelectric resources in Maine. NSTAR and National Grid have contracted for 77.5% of Cape Wind's proposed 468MW of capacity.

payment obligations. With the exception of the Cape Wind contracts, it is expected that the payments to purchase Section 83 power will be roughly equivalent to the revenues for reselling the power, and thus a 'wash' from the ratepayers' point of view. The direct payment by utility ratepayers for the Cape Wind contract will likely exceed market revenues, at least in the early years of the contract. Finally, as with EE and net metering, the injection of the Section 83 wind-powered resources contributes to suppressing of wholesale prices in New England, further lowering in the short-term the wholesale electricity prices for consumers in Massachusetts and other states.[22]

Renewable Portfolio Standards

The GCA significantly expanded the state's renewable portfolio standards, creating two classes of eligible renewable resources, and ultimately requiring that retail suppliers in the state meet at least 15 percent of sales in Massachusetts through the purchase of eligible new (Class I) renewable resources. Class I resources include new renewable resources, in operation by 1998, and Class II includes resources that came into operation prior to 1998. An eligible renewable energy source includes solar PV or solar thermal; wind; ocean thermal, wave or tidal; fuel cells using renewable fuels; landfill gas; new/incremental hydroelectric; and low-emission advanced biomass or geothermal. Prior to the GCA, the RPS program was fixed at four percent of retail sales.

An additional component of GCA implementation involved a solar "carve out," which mandated that a percentage of each utility's electricity must come from a solar PV resource built or installed after 2008. This solar carve out requirement is a part of other Class I renewable resource requirements, meaning that meeting the solar carve out requirement also meets the utility's Class I requirement. To meet the standard for eligibility, solar resources must meet certain criteria, including being located within Massachusetts, being smaller than 6 MW, and being privately funded. The requirement in 2011 was 0.1627 percent of retail sales, and has grown to 0.9481 percent of retail sales in 2014.[23]

The GCA also created an Alternative Energy Portfolio Standard (AEPS), with the Massachusetts Department of Environment Protection setting an annual standard. AEPS-eligible resources include fossil fuel gasification with carbon capture and sequestration (CCS) technology; combined heat and power; flywheel energy storage; paper-derived fuel; or energy efficient steam technology. All AEPS requirements are currently met by resources located in Massachusetts.

At 15 percent of retail sales, eligible Massachusetts RPS/AEPS generation and Alternative Compliance Payments (ACP) represented just over 7,000 MWh of generation in Massachusetts, the rest of New England, New York, and Eastern Canada in 2011. By 2020, this will rise to 27 percent of retail sales, representing approximately 14.2 GWh of generation and ACPs. Nearly all of

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[22] All Section 83 purchases are for resources that have near-zero variable costs, meaning they will bid close to zero in the ISO-NE energy markets, with the effect of displacing generation from more expensive resources that otherwise would be setting regional energy prices on the margin.

[23] See the current status of the solar carve out at http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/rps-solar-carve-out/current-status-of-the-rps-solar-carve-out-program.html.

this is eligible solar PV and wind resources, with similar price suppression effects in wholesale markets.

Green Communities

In addition to the policies affecting provision of electric and natural gas service in Massachusetts, the GCA has a number of other programs that represent dispersed opportunities and requirements for municipalities and businesses, as well as several smaller pilot programs related to the electric sector. These include smart grid pilot programs by electric utilities, building efficiency standards, and state power purchasing and building efficiency commitments.

Finally, the GCA contains a specific program to foster community-based EE and renewable energy development. For the Green Communities Program, the GCA provided for up to $10 million per year in technical and financial help to municipalities to promote community-based energy efficiency and the financing, siting and construction of renewable and alternative energy facilities. In order to receive assistance under the Green Communities Program, the city or town must adopt special zoning and expedited permitting procedures for renewable/alternative energy generating, manufacturing, and research and development facilities; develop an energy use baseline and provisions to lower energy use by 20 percent within 5 years; and pursue lower-impact programs in vehicle purchasing and water use. Funding for the Green Communities Program includes monies from the Regional Greenhouse Gas Initiative, the Renewable Energy Trust Fund, and other sources.

For example, the City of Boston has received over $1 million to reduce its energy costs through GCA grant money, investing directly in the community for such initiatives as auto igniters for natural gas streetlights, lighting controls at municipal ball fields, and upgrading or installing energy management programs at Copley Library and other branch libraries. The City of Worcester has received almost $1 million through Green Community grant money, and has invested in a residential stretch-code implementation program and outreach campaign.[24]

Summary of GCA Program Impacts

The GCA is a wide-ranging set of legislation with a number of initiatives that significantly affect regional demand for electricity (and to a lesser extent, natural gas), the mix of the region's power supply, and price formation in New England's wholesale energy, capacity, and REC markets. Most of these impacts tend over time to decrease total energy consumption and the state's peak power demand. They add renewable resources and increase generation from low- or zero-carbon resources within Massachusetts. And they lower wholesale electric energy prices.

In sum, the first six years of implementation of the GCA will generate (by 2016) at least the following changes relative to no GCA:

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[24] A "stretch-code" is a local-option building code that sets a standard of 20 percent to 30 percent more energy efficient than the Commonwealth's recently adopted statewide code. Green Communities Division, Massachusetts Department of Energy Resources.

- GCA electric-utility efficiency programs that end up decreasing Massachusetts consumers' electricity use by 3,617 GWh (or by six percent), and reducing annual peak load by 614 MW, or five percent of peak load;
- Gas-utility efficiency programs lead to lower use of natural gas for heating, cooking and process needs by 4.6 million MMBtu;
- Renewable policies already implemented to date lead to the installation of approximately 715 MW of solar PV capacity, plus approximately 1,000 MW of new wind capacity resources in Massachusetts and the rest of New England (growing to approximately 2,000 MW by 2025); and
- The Green Communities program has led to 123 cities and towns to become Green Communities, receiving $30 million in funding generating substantial savings and emission reductions.

Program Costs

A number of sources provide the up-front funding to pay for these GCA programs. There is an initial investment period – the first six years of the GCA – in which electricity and natural gas customers fund EE and renewable program costs of approximately $2.7 billion.[25] (The returns on this investment accrue over the period from 2010 through 2025, such that the average residential electricity customer ends up paying roughly seventy cents per month on average for typical residential consumers over the study period.[26])

These customer bill impacts reflect direct funding of EE and renewable energy programs as well as indirect impacts of those programs on utility rates. Although the state's utilities administer EE programs, some of the costs of those programs are collected from electric and natural gas utility ratepayers.[27] Additionally, when implementation of EE programs lead to lower use of utility service and therefore lower revenues to the utilities, the lost revenues are recouped from all customers via the state's revenue decoupling policy. Because a certain portion of utilities' delivery costs are fixed and cannot be avoided through reduced consumption, the GCA and DPU regulatory policies generally allow utilities to recover from all customers those revenues that are lost due to EE and net metering installations.

There are other costs to parties in Massachusetts. For example, even though the utility EE programs provide financial incentives, the businesses and homeowners that install EE measures or on-site wind and PV systems typically pay some portion of the costs of those installations. These can be a relatively large or small share of the installation costs, depending upon the measure (e.g., window replacement, insulation, or boiler replacement; rooftop solar). Such costs

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[25] This number is expressed in nominal dollars.

[26] This assumes an average residential consumer in Massachusetts uses approximately 625 kWh per month, based on 2012 retail electricity sales and consumer data filed with the Energy Information Administration for Massachusetts.

[27] The total cost – to the utility – of EE programs is first reduced through (1) proceeds earned in wholesale markets by bidding the demand reductions associated with EE into regional capacity/energy markets; and (2) state proceeds from the sale of RGGI auction allowances. Remaining costs are collected from customers through an EE surcharge on customer bills.

are directly born by participants in the programs (who by definition obtain benefits (cost reductions) greater than their actual costs).

The GCA allows utilities that invest in the construction of solar PV to petition the DPU for approval of associated costs, plus a reasonable return on investment. All of the energy, capacity, and REC value of such projects, in turn, is credited to ratepayers. Similarly, to the extent the cost of long-term renewable contracts differs from the prevailing price of electricity in wholesale markets, the difference is collected from (or refunded to) electric utility customers. Finally, utilities and competitive suppliers will include the cost of procuring sufficient RECs to meet RPS requirements in the price they charge for wholesale power.[28]

[28] Retail suppliers – including utilities providing default service – must purchase RECs sufficient to meet RPS requirements (e.g., in 2020 a supplier must purchase Class I RECs equal to 15 percent (in MWh) of their total retail sales of electricity in the year). Suppliers may alternatively make an "alternative compliance price" (ACP) payment if sufficient RECs are not available in the market, or if the price of RECs is higher than the ACP. The ACP is set, and may be periodically adjusted, by DOER, and ACP rates for the 2014 Compliance Year are $66.16/MWh for RPS Class I.

3. STUDY PURPOSE AND APPROACH

Study Purpose and Method

The GCA represented a significant shift in Massachusetts energy and environmental policy – to address or mitigate the social, economic and environmental risks associated with climate change, foster fundamental change in how we generate and use energy, and mitigate other health and environmental impacts of fossil fuel use.

Because there are both monetary costs and benefits associated with GCA implementation, a fundamental question is: on net, how has GCA implementation affected the Massachusetts economy, considering economic costs and economic benefits? How does it affect the cost to light and heat homes and operate businesses? How do the flow of investments and changes in resource use affect Massachusetts companies' revenues, the number of jobs in the state, and the overall productivity of the Massachusetts economy?

This is the purpose of this study. We set out to examine the various monetary and economic effects of the GCA on the Massachusetts economy. This is not a comprehensive societal benefit/cost analysis, however, because we did not attempt to quantify the impacts of GCA changes to our energy system on human health, safety, or the environment, or to quantify the risks of climate change or the value in reducing or mitigating that risk. It does not review the economic or non-economic benefits or costs to the residents and businesses of any other state. The analysis did not explore implications for investment conditions in local and regional electric energy markets or structural changes in the Massachusetts economy. All of these other impacts – non-monetary ones in Massachusetts, monetary and non-monetary ones outside of Massachusetts, or unintended structural impacts on investment conditions – may be very important over time, but they are beyond the scope of our analysis.

The first years of GCA implementation provide a substantial amount of direct history and experience, along with a large body of price, savings, and cost data and evidence sufficient to be able to assess its direct and indirect economic impacts within the state of Massachusetts.

Our analysis is grounded in actual implementation details and real data reflecting the investment carried out or approved to date. Based on those actual investments, inputs reflect costs to consumers and energy market participants, reductions in energy consumed, the generating capacity of new and existing power generating resources, and spending in Massachusetts as a result of these programs.

The study is a snapshot of the known impacts of the first six years of GCA implementation, coinciding with the first two full cycles of three-year EE plans. The analysis did not forecast future developments under the GCA beyond the ongoing effects of the investments that have already occurred or that result from action already taken to approve actual renewable energy contracts, to achieve RPS requirements, and to full the energy efficiency programs/plans approved by or filed with regulators. Specifically, the analysis does not forecast or assume continued implementation of the GCA (and as authors, we were not asked to nor did we take a position on such). The purpose of applying this "snapshot" model of a defined period of GCA implementation and impact was to minimize uncertainty in results, and to take a conservative approach to the accounting for GCA program benefits.

The analysis is structured to compare two cases: (1) the status quo, representing conditions that have evolved with implementation of the GCA; and (2) a counterfactual case representing conditions that would have existed without GCA implementation. We first modeled impacts on the electric system associated with GCA-driven changes in generation and load, and then modeled how these changes – along with the direct investment of GCA expenditures and costs of the program – affect the Massachusetts economy from the perspectives of economic output and jobs.

The purpose of our analysis is to follow this money and identify the economic impacts of its use. Across the specific six-year period of initial GCA implementation, the initial investments in various EE and renewable energy programs of the GCA amount to approximately $2.7 billion (paid through electricity and natural gas bills of Massachusetts consumers).[29] There are also dollars spent by the households and businesses that install net metered renewable systems or participate in EE programs. Over the long term, electricity customers pay for the power from long-term contracts for renewable projects and for the REC costs associated with the RPS program. These dollars, in turn, are invested in development, manufacturing, construction and implementation activities both within and outside Massachusetts.

Specifically, we track the path of GCA dollars as they are collected from electric and natural gas customers by utilities (or are directly invested by home and business owners for EE and renewable resource installation), are paid out to developers and contractors, and then roll out into the economy in one way or another.

The analysis is unique in that it focuses on the actual impacts of investments and contractual commitments that are known with a high degree of confidence – all of the program expenditure data come from public reports or regulatory filings. All of the values for EE savings come from comprehensive monitoring and verification (M&V) activities and reports, or DPU-reviewed savings estimates based on past M&V activity. And all of the annual renewable generation output data is based on resource output from actual operation of wind and solar PV resources or from output profiles based on meteorological data and operational experience.

Our analysis *could have* projected continued implementation of GCA programs well into the future, based on the law and implementing regulations, and on forecasts of future expenditures, contracts, and construction activities. Such forecasts would allow for a much longer modeling period, for tracking EE savings and renewable energy output, and would better capture expectations for continued implementation of GCA programs and ongoing growth in EE and renewable energy investment (and associated power sector impacts). Instead, the analysis only assumes GCA implementation for the first six years, and truncates all EE savings at 10 years after installation and all GCA-based renewable generation at the end of the modeling period (2025). The purpose of applying this "snapshot" model of a defined period of GCA implementation and

[29] This number is expressed in nominal dollars.

impact was to minimize uncertainty in results, and to take a conservative approach to the accounting for longer-term GCA program benefits.

Additionally, we could have looked at changes in money flows outside of Massachusetts. For example, GCA likely affects – positively and negatively – companies that do business in Massachusetts but that are located in and owned by parties outside of the state. We did not look at the impact of lower earnings by companies headquartered out of state but that have shareholders who reside in Massachusetts. We could have tried to model positive and negative second-order effects on structural relationships in various sectors (including the electric sector) or on the investment climate in Massachusetts for non-renewable generating resources that might result from price suppression in electricity markets affected by decreased demand and increased renewable energy. While such issues could be important over time, they were beyond the scope of our analysis.

Overview of the Study Approach

Thus, our analysis only assumes GCA implementation for the first six years, and assumes all EE savings expire at the end of their 10 year useful life. We assumed that renewable generation resulting from the GCA remains in effect and produces energy through the end of the modeling period (2025), though we recognize that the useful life of these generating assets may extend beyond this period.

Within this timespan, we tracked the revenues collected from or paid by Massachusetts consumers. We examined GCA expenditures on EE and renewable programs and projects. We measured how such changes affect the quantity of power consumed, the price of power on the margin in wholesale markets (and thus the price charged to consumers), and the types of generation used to meet electricity demand in Massachusetts. We traced reductions in fuel use for heating, cooking, and process needs, because these affect the total cost to residential and business consumers for heating, air conditioning, lighting, appliances, and commercial and industrial processes. Finally, we tracked how consumer costs or savings affects their spending, and how the money for GCA programs is spent in the Massachusetts economy (or outside the state). These dollars include spending for contractors to install EE measures or build renewable resources; for development activities; for manufacturing of associated equipment; and for the profit (or loss) of Massachusetts-owned companies.

By carefully examining the dollar flows associated with the implementation of the GCA, and comparing that to a counterfactual case assuming no GCA implementation, we were able to measure the extent to which GCA program implementation represents a positive or negative impact on the economy of Massachusetts.

There were four major elements of our review, each of which is discussed in more detail below:

1. We first established the **scope and overall framework of the analysis**, to create as much as possible an integrated analytic framework that separates and highlights Massachusetts impacts based on known historical program implementation data in the first six years, on the one hand, from other factors and impacts that come from outside the state or that are associated with forecasts or projections.

2. Next we conducted a thorough review of **data and information on revenues collected from ratepayers or otherwise spent by residents and businesses that participate in GCA programs**. These data were gathered from public sources, with the goal of tracking with as much accuracy as possible exactly how GCA costs and revenues have been collected, spent, and disbursed over the first six years.
3. Third, we modeled **electric sector outcomes** based on the changes in electricity demand and supply that result from GCA-related investment in energy efficiency and advanced energy technologies. Our electric sector analysis was conducted using Ventyx's PROMOD model.[30]
4. Fourth, we modeled **macroeconomic outcomes of the GCA**, combining the dollar-flow impacts on the electric sector (positive and negative) with the dollar flows (positive and negative) in various in other sectors of the Massachusetts economy. This produced an overall picture of how GCA program implementation has directly and indirectly affected the economy. Our macroeconomic analysis was conducted using the IMPLAN model.[31]

Scope of Analysis

Our core approach was to examine changes in power system dispatch and the economy under two scenarios: the "GCA case," which is effectively the world as it has actually evolved; and the counterfactual "no-GCA case," which adjusts conditions in the actual world to remove the effects of the GCA, as if it had never been passed or implemented. The difference in economic impacts between the two cases reflects the incremental impacts of the GCA programs to date.

In constructing the scope of our analysis, we were guided by three key objectives: First, we wanted to focus on impacts only within Massachusetts (a geographic perspective). While some GCA-related spending and associated regional power system impacts flow outside of Massachusetts,[32] we did not try to capture or report those impacts in our analysis. Similarly, in the power system modeling, our evaluation of impacts on power plant owners (also referred to as producers or generators here) and energy consumers is limited to those located within Massachusetts.

Second, we wanted to identify near-term and longer-term impacts associated with GCA's implementation during the first six years only (2010–2015) (a temporal perspective). From this perspective, we tracked only the impacts of GCA associated with investments, spending, and contractual obligations that arise from GCA-related activities in this first six years. (We did not, for example, assume any more EE spending beyond the most recently-approved three year plans,

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[30] PROMOD is an electric system dispatch model that simulates the operation of an interconnected utility power system, taking into account constraints on the operation of the grid. The PROMOD model and our analysis of electric sector impacts are described in more detail in the Appendix.

[31] The IMPLAN model is a social accounting/input-output model that replicates the structure and functioning of a specific economy. IMPLAN and our analysis of macroeconomic impacts are described in detail in more detail in the Appendix.

[32] Examples of GCA spending and impacts that do not directly affect Massachusetts include the lowering of regional wholesale power costs in other New England states, GCA money spent for the manufacture (outside Massachusetts) of light bulbs or insulation used in energy efficiency programs, or flows of dollars to the federal government associated with changes in income.

nor did we include ratepayer contractual obligations for installations or purchase commitments entered into after 2015.)

Third, we wanted results that were grounded as much as feasible in actual, known expenditures, programs, and impacts (an empirical perspective). This required us to make some nuanced adjustments. We tracked actual dollars collected from ratepayers or invested by residents/businesses (for on-site EE or renewable installations) or power project developers associated with the first six years of the GCA. Most of these dollars have actually been collected and/or spent (reducing disposable income) or invested in projects (e.g., to construct larger renewable projects) in those first six years. But there are two cases where implementation of the GCA in the first six years leads to money that is collected or spent beyond year six: (1) for construction of large renewable projects, where construction is not expected to be complete until after 2015; and (2) for payments under long-term renewable contracts, where ratepayers continue to pay for contractual obligations for the full term of the study period.

With this scope of analysis, we observed that for the dollar flows in the electric system, the impacts of the GCA-related investments begin to show as the money is invested – that is, incremental EE savings start to accrue as a function of when incremental EE spending happens, and BTM and grid-connected renewable resources begin to affect power system operations as the installations are complete. But for the most part, these impacts continue for the full study period – EE savings associated with EE investments in a given year are assumed to continue for 10 years; output from renewable resources resulting from GCA programs is assumed to continue through to the end of the study period (2025). The macroeconomic impacts, by contrast, reflect the majority of costs being incurred in the first six years, but also reflect ongoing impacts associated with continued spending obligations and, more importantly, EE savings and renewable output over the full study period.

Data Collection and Processing

Our analysis began with the collection and processing of data related to GCA program implementation in Massachusetts, and related to the power system in New England. This process also involved the translating of expenditures for energy efficiency measures into impacts on power system energy consumption and electricity peak loads in various seasons and days of the year. In the end, we were able to obtain most of the necessary information and data from state documents and other public documents and filings.

We characterized the power system using data consistent with that used by ISO-NE for planning purposes, updated to include the most recent information on asset addition and attrition, and fuel pricing. We characterized the effects of the GCA-funded activities, programs, and investments through data from public sources and filings. By "effects," we mean the tangible results of the expenditures that are significant or important from the standpoint of measuring economic impact through the PROMOD and IMPLAN modeling effort. For example, what are the annual household electricity savings, on- and off-peak, associated with an appliance rebate program to replace old air conditioners with new, efficient ones? How many MWh of generation will flow annually from a wind or solar photovoltaic system built or contracted for by a utility, or installed on a rooftop due to the net metering program? Identifying such effects involved (1) collecting data on actual investments, contracts and installations, (2) reviewing and processing these estimates for consistency of assumptions and calculations, and (3) using conservative estimates where data were missing, incomplete, or inconsistent.

The following provides a summary of our data sources; full detail on data sources and assumptions may be found in the Appendix.

- *Electrical Load* representation – historically and forecast – is based on ISO-NE's CELT Report and hourly zonal data, and Ventyx Simulation Ready Data.
- *Existing Generation* is also based on ISO-NE's CELT Report and Ventyx Simulation Ready Data.
- *New Generation and Retirements* over time were developed based on a review of Ventyx Simulation Ready Data, SNL Financial data, ISO-NE Forward Capacity Market results, and ISO-NE publications related to the status of non-price retirements available at the time of the study.
- *Fuel Prices* were developed using a combination of data and forecasts from SNL Financial, the Energy Information Administration's (EIA) 2013 Annual Energy Outlook, and Ventyx Simulation Ready Data.
- *EE Savings and Load Reduction Profiles* were based on the filings made with the DPU by Massachusetts state utilities.
- *Behind-the-Meter Installations* were developed using the Massachusetts System of Assurance of Net Metering Eligibility, and reports from the Massachusetts Department of Energy Resources.
- *Grid-Connected Installations* built by utilities or resulting from utility long-term contracts and the Massachusetts RPS were identified through Massachusetts state utility filings with the DPU and ISO-NE RPS forecasts.
- *Discount rates* were developed using reports from the White House Office of Management and Budget, and the US Environmental Protection Agency.
- *Other data sources* used in constructing the GCA and no-GCA case include National Renewable Energy Laboratory JEDI models; ISO-NE's Offer Review Trigger Prices 2013 Study; the Analysis Group Assessment of the Impact of ISO-NE's Proposed Forward Capacity Market Performance Incentives; the US Department of Energy REC price reporting; Energy Information Administration energy and electricity price data; and Massachusetts Department of Energy Resources' Annual Compliance Report for Massachusetts' RPS and APS.

Modeling Approach

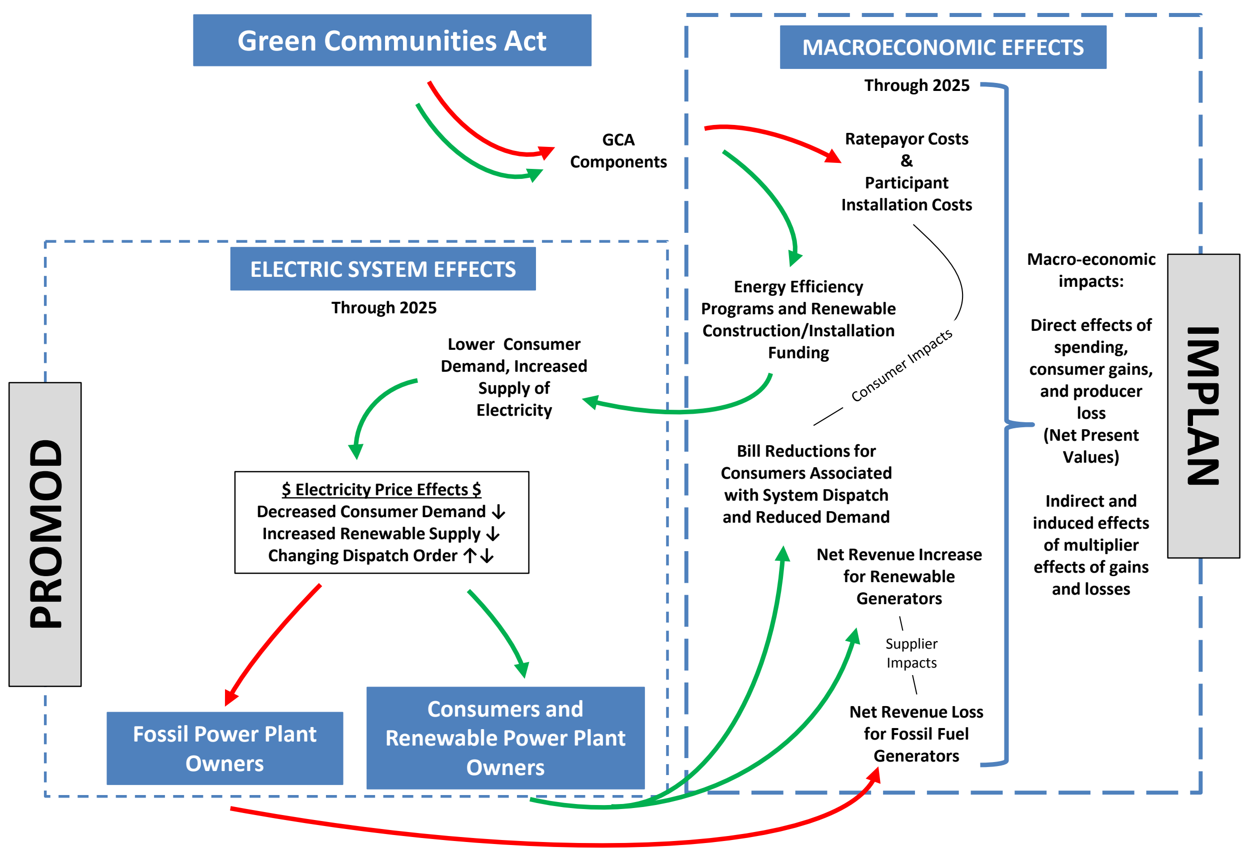
Overview

Since the purpose of the analysis is to track the impact on the Massachusetts economy of how the GCA has affected money and power system flows, we needed to (1) track the flow of GCA dollars and impacts through the economy, and (2) construct a counterfactual electric system that removes the dollars and impact of GCA implementation. We provide the details of our assessment tools in the Appendix, which describes the IMPLAN and PROMOD models in greater detail.

With respect to impacts on the general economy, GCA implementation has two effects. First, when utilities and/or residents/business owners fund an activity (such as energy efficiency measures or renewable resource development and installations), those monies have a direct impact in the form of purchases of goods and services in the Massachusetts economy, as well as a cost to the consumers who have less money in their pockets as a result of this funding. Second, the implementation of GCA programs creates changes in the power sector, in the form of changes in power plant owners' costs and revenues, prices bid into wholesale electricity markets, and consumer spending for power. In aggregate, these changes in spending lead to gains and losses to power plant owners and consumers, which, in turn, affect economic flows in the macroeconomy.

To estimate these impacts on the economies of RGGI states, we model changes to the electric system and macroeconomic outcomes. The general flow of data and modeling outcomes is depicted in Figure 1.

Figure 1
Flow of Data and Modeling Outcomes



Our modeling approach combines analysis of power sector effects (through modeling using PROMOD), and analysis of macroeconomic effects (through use of IMPLAN). The foundation of our modeling analysis is, in effect, a comparison between two scenarios run through the models.

In the IMPLAN analysis, we start with economic relationships that exist among providers and users of goods and services in Massachusetts, and then we introduce the direct expenditures (related to GCA programs) and the revenue gains and losses to electricity consumers and power producers. In the PROMOD model, we run a dispatch of the New England power systems "with" and "without" the GCA, and include in each run the same core conditions: power system infrastructure both in place and as it evolves over the modeling period (that is, transmission configurations and power plant additions and retirements); local and regional forecasts of electric energy and peak load by service territory over the modeling period; projections of fuel prices and allowance prices for CO_2, NO_x and SO_2; etc.

The two cases in PROMOD can be described as follows:

- GCA Scenario – In the GCA scenario, the power system is modeled as it is. That is, the GCA case represents the world as it has evolved with GCA in place. It includes all of the programs, measures, investments, and funding that are associated with the first six years of GCA program implementation, and all of the impacts on the power system and economy associated with GCA implementation.
- No-GCA Scenario – In order to create the counterfactual against which we compare and contrast the GCA case, we create a scenario configured to represent the power system and economy as it would have progressed absent implementation of the GCA. In order to do this, we relied on all of the data and representations of GCA investments and associated effects described in Section 2, and removed those investments and effects from the GCA scenario.

We then traced the dollar differences in these two PROMOD runs (with and without GCA) through the macroeconomic IMPLAN model to capture the impacts of these electric sector outcomes; we also inject funds related to utility, resident/business owners', and resource developers' direct expenditures of GCA-related investments in IMPLAN.

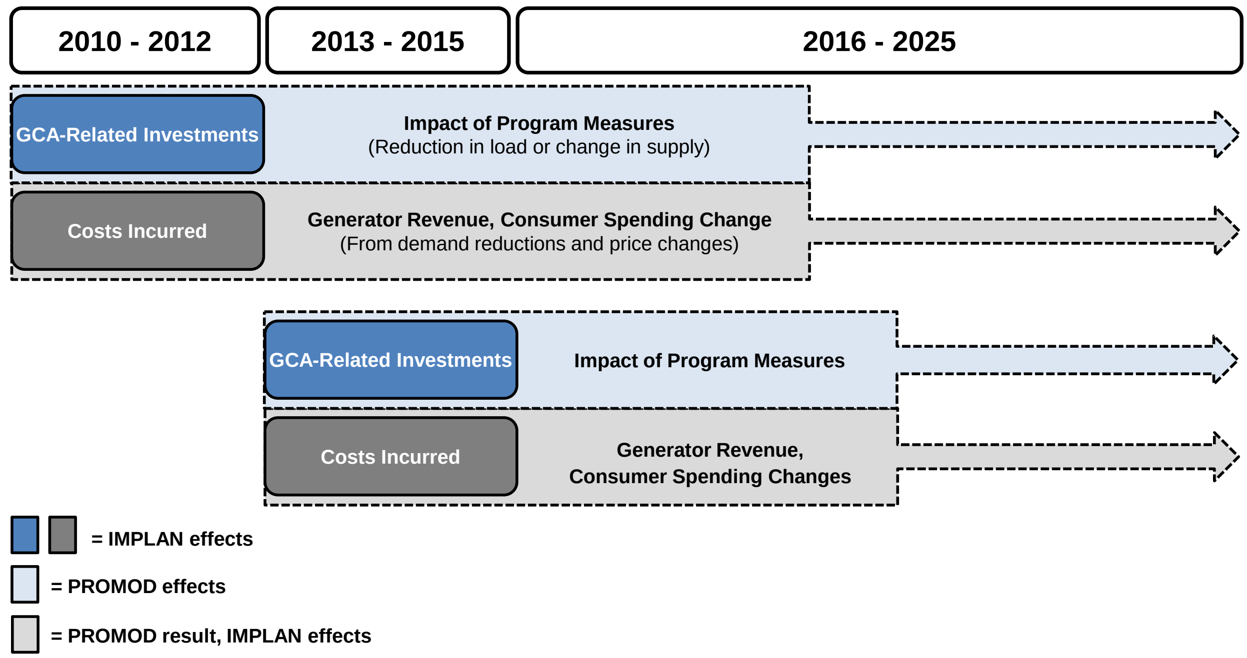
Modeling Timeframe

Figure 2 captures in schematic form how GCA program costs and effects were represented in the PROMOD and IMPLAN modeling. More detail on how the modeling was carried out is presented in the Appendix, but in summary the items to note in this figure are the following:

1. For each of the two three-year EE planning periods, there are costs collected from consumers and expenditures made by utilities, consumers, and resource developers to install EE measures and develop, construct, and/or install BTM or grid-connected renewable resources. These dollars flows, represented in blue and red in Figure 2, are included in IMPLAN modeling as they occur. While the majority of such dollar flows happens within the six-year period, it should be noted that some additional dollar flows (not depicted in the graphic) may continue beyond 2015, for long-term contract obligations and for projects that do not complete construction by the end of 2015.
2. The impact of these investments on total consumption and electricity market price outcomes continues throughout the modeling period, as EE measures continue to

generate savings (relative to the no-GCA case), and renewable resource installations continue to generate output. Thus, the impact of the investments in the two three-year planning periods continues to affect the economy, and those impacts – represented in green and grey in Figure 2 – are modeled in both PROMOD and IMPLAN for the duration of the study period.

Figure 2
Representation of GCA Program Costs and Impacts through PROMOD and IMPLAN Modeling



By constructing the analysis in this way, we were able to isolate our measurement of impacts to "known" outcomes associated with only the first six years of GCA implementation, and with impacts limited to Massachusetts consumers and businesses.

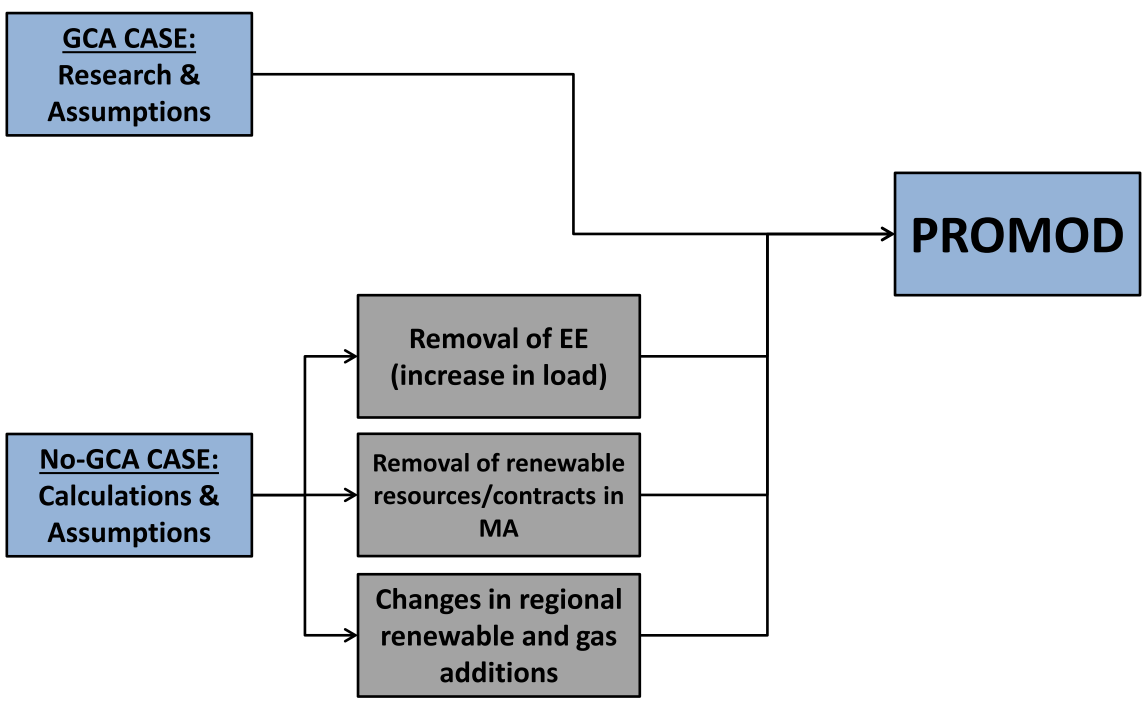
Power Sector Analysis

The GCA has three distinguishable effects in wholesale power market operations, with a consistent influence on electricity market outcomes. First, EE measures decrease overall electric load in most hours, in effect lowering the demand curve in most hours of the year. Second, investments in BTM wind or solar PV installations have a similar effect – namely, since BTM generation either decreases the need to draw power from the grid or (when output exceeds consumption) pushes power onto the grid at the distribution level, it appears from the perspective of wholesale market operations as a reduction in demand across the region. Finally, increases in grid-connected renewable resources add to total generation resources in wholesale markets at an overall variable cost of generation near zero, in effect "pushing out" the supply curve for generation.

The net effect of all of these policies is to change the generation that is needed on the margin in many hours of the year, thereby meeting wholesale electricity demand from lower-priced resources. In short, since the market in New England clears at the price of the last unit dispatched, the GCA programs that reduce demand and push out the supply curve lead to lower wholesale prices than in the no-GCA case.

Using the PROMOD power system dispatch simulation model, we quantified these net impacts on regional and local system loads, power prices, and revenues to power producers associated with implementation of the GCA. (See the Appendix for a detailed description of the PROMOD modeling platform, whose core logic is explained briefly below.) These relationships are summarized in Figure 3. Using PROMOD, we created the "with GCA" case (benchmarking the modeling results to the actual data), and then constructed a counterfactual "no-GCA" case. Comparing the results of the two cases provides information about the incremental effect of GCA on power system users and producers.

Figure 3
Diagram of PROMOD Modeling Inputs and Outputs



PROMOD is an effective tool for estimating the potential impact of different power system scenarios in competitive markets. Traditional cost-minimizing strategies in the dispatch of power systems involve use of production-cost information to determine which power plants operate at different times of the day to meet changing load conditions. In competitive wholesale electric market regions like the Northeast and Mid-Atlantic regions, decisions on which power plants to turn on and off are made based primarily on bids submitted by power plant owners indicating the price at which they are willing to supply power into the markets. Provided the market is sufficiently competitive, price bids should approximate marginal production costs of the facilities in the system. Generally, prices in wholesale markets are set hourly based on the last generating unit dispatched – that is, the most expensive unit that was needed to meet hourly load.

The PROMOD power system model is configured to simulate the dispatch of the power system on an hourly basis based on power plant marginal costs, subject to various operational and transmission system constraints that can alter dispatch order (and thus prices) in real time. The PROMOD model simulates system dispatch based on, and reflecting: (1) the operational characteristics and marginal production costs of every generating facility in the power region being studied (in this case, New England); (2) the configuration of, and limits on transfers of power across, the transmission system, comprising every transmission line and other system components in place; and (3) algorithms designed to reflect the operational constraints of power plants, such as the time it takes to start units and to ramp them up to various power levels, the minimum time they must be on, and the minimum time they must be off. Given the level of detail in how PROMOD represents the power system – that is, down to very small power plants and specific transmission system components and limits – it is able to model and represent power prices, unit output, emissions, consumer costs, producer revenues and other factors on an hour-by-hour basis, and with a high degree of geographic resolution (that is, down to a utility's service territory, or a specific substation).

Given this level of detail, we were able to model investments in energy efficiency and the development of new renewable generation resulting from the GCA at a detailed state- and utility-specific level. This allowed us to capture the impact of such investments on the prices that consumers pay – and that power producers are paid – on an hourly basis. As shown in Figure 3 above, we simulated the dispatch of the New England system for each hour of the modeling period (January 2010 through December 2025) for both the "GCA" and "no-GCA" cases. Based on the output of those two cases, we calculated changes in (1) unit dispatch/annual generation and emissions, (2) wholesale electric prices, (3) payments to power producers, and (4) payments by consumers.

We used the PROMOD output and associated calculations of changes in generator and consumer prices, revenues, and payments in two ways. First, the data were used to describe the impacts on generators and consumers from the perspective of the electric system only – that is, how much more or less do power plant owners get paid as a result of GCA program investment effects? How much more or less do Massachusetts consumers pay for electricity as a result of GCA program investment effects? How do these electric system impacts change with time?

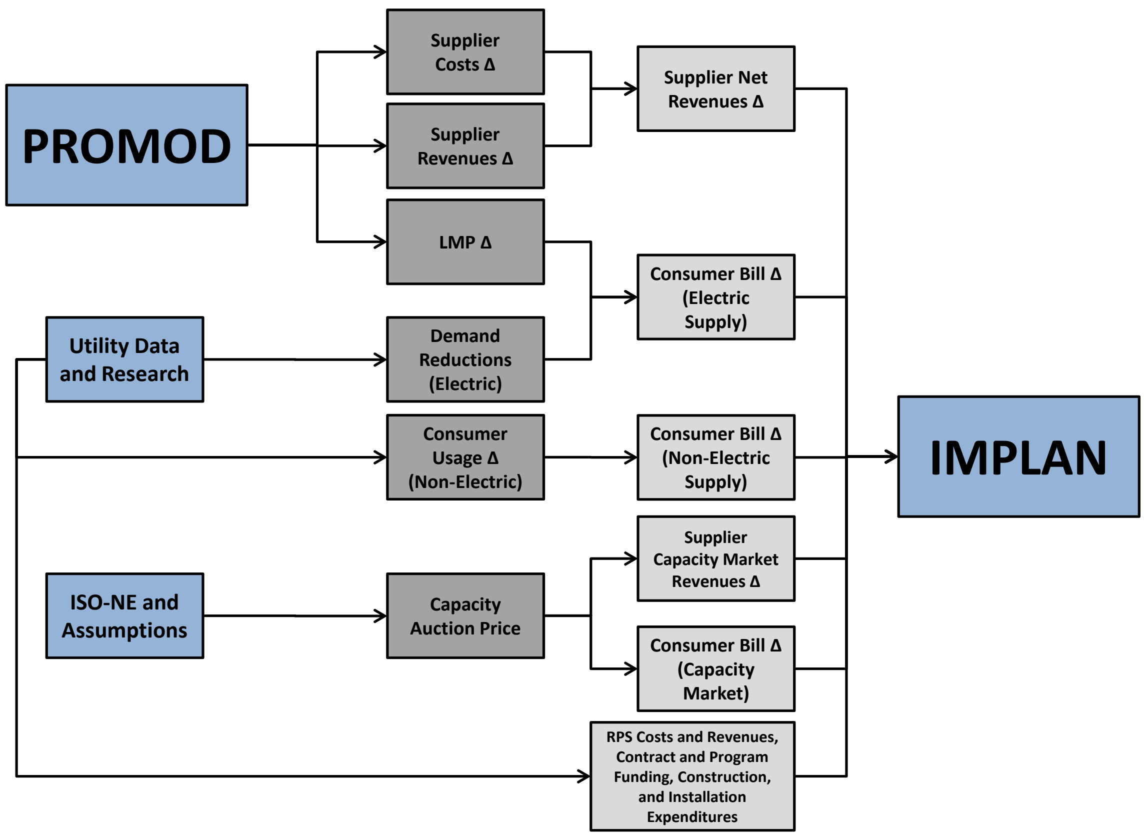
Additionally, we used the output data from PROMOD as inputs to the IMPLAN model. From a macroeconomic perspective, the end result of changes in power system costs, revenues, and payments are (a) changes in economic conditions for power plant owners (affecting their ability to spend and save in the general economy), and (b) changes in the level of disposable income enjoyed by consumers as a result of the GCA (e.g., relating to their having higher or lower electric bills), which affects their spending and saving in the general economy. Consequently, changes in these two factors serve as inputs to the general economic model (described below), along with other categories of GCA program investment.

Macroeconomic Model

Changes in power producer revenues and consumers' electricity bills associated with electric system impacts lead to larger direct and indirect impacts in the economy as a whole. Other economic impacts occur – namely, those that flow from the actual direct spending as a result of GCA program implementation and incentives. For example, these include utility spending on EE and solar PV construction, and the investments made by residential and business consumers for EE measure and net metering resource installations.

Consequently, in order to model macroeconomic impacts, we combined the changed revenues and spending that were outputs of the PROMOD modeling, together with all categories of the direct investment as a result of the GCA, as inputs to the macroeconomic model, IMPLAN. The relationship between PROMOD and IMPLAN, and the source of additional inputs to IMPLAN, are shown in Figure 4 (and explained in more detail in the Appendix).

Figure 4
Relationship of PROMOD and IMPLAN Models for GCA Investments and Impacts



IMPLAN is a social accounting/input-output model that attempts to replicate the structure and functioning of a specific economy, and is widely used in public and private sector economic impact analyses. It estimates the effects on a regional economy of a change in economic activity by using baseline information capturing the relationships among businesses and consumers in the economy based on historical economic survey data that track flows of money through the economy. IMPLAN tracks dollars spent in a state or region, including dollars that circulate within it (e.g., transfers of dollars from consumers to producers), dollars that flow into it (e.g., purchases of goods and services from outside the local economy), and dollars that flow outside of it (e.g., payments to the federal government). The model thus examines inflows, outflows, and interactions within the economy under study.

The IMPLAN model allows one to investigate interactions in Massachusetts, and to calculate various economic impacts in that economy when a new activity (such as investments in energy efficiency, gained or lost revenues for owners of power plants) involves money flows around the economy. Specifically, the model captures various impacts, including:

- *Employment impacts* (the total number of jobs created or lost);
- *Income impacts* (the total change in income to employees that results from the economic activity); and
- *"Value-added" impacts* (the total economic value added to the economy, which reflects the gross economic output of the area less the cost of the inputs).

In our analysis, we report employment impacts and the "value-added" impacts produced by the model, reflecting the combination of the following economic effects of the change in money flow associated with the GCA:

- *Direct effects:* the initial set of inputs that are being introduced into the economy. In our study, this included the direct effects of the GCA on owners or developers/installers of power plants and BTM resources as a whole, on energy "consumers" (end users of electricity, natural gas and heating oil), and use of GCA-related proceeds to buy goods and services in the economy (e.g., investment in energy efficiency and renewable resource installations).
- *Indirect effects:* the new demand for local goods, services and jobs as a result of the new activity, such as the purchase of labor to retrofit buildings with energy efficient measures, or to train workers in these skills. Some GCA program investments lead to payments for things outside the local region (e.g., the purchase of efficient lighting equipment or solar panels manufactured outside of the Massachusetts), and thus represents a way that such funds do not stay within the local economy after having been generated through collection from ratepayers or investments by residents, businesses, or power plant developers+.
- *Induced effects:* the increased spending of workers resulting from income earned from direct and indirect economic activity.

Additional Modeling Factors

To calculate the impacts of the GCA, we needed to make a number of simplifying assumptions about the systems and economies that we are studying. These assumptions relate to: (1) the relevant (geographic, temporal) boundaries around the analysis, (2) the methods for putting dollar flows occurring during different time periods into a common economic framework; (3) key modeling parameters in the power system; and so forth. We highlight a few of these below.

Discount Rate

Our analysis involves the assessment of costs (e.g., expenditures and investments, decreases in revenues) and benefits (e.g., lower electricity bills for consumers, added value in the economy) that occur in different periods of time. We examine the flow of dollars associated with investments and expenditures primarily in the period 2010-2015, and the impact of this in electricity market outcomes and the general Massachusetts economy from 2010–2025. Thus, the study period, in one way or another, spans from 2010–2025.

To compare these benefits and costs properly, we discounted all dollar flows into net present values as of 2013. We calculated the net present value by applying an appropriate discount rate to dollar flows in different years, and then subtracting the sum total of discounted costs from the sum total of discounted benefits.

Our analysis required choosing an appropriate discount rate, one that must reflect the preferences for money today versus in the future for various constituencies – power producers, who are largely private enterprises, consumers (e.g., households, businesses, government energy users), and others. Choice of appropriate discount rate needs to properly reflect the opportunity costs of these various private and public entities in society.

We have chosen to use two discount rates, as recommended in situations where an analysis involves money flows to various entities in society over different periods of time, especially when "there is a significant difference in the timing of costs and benefits, such as with policies that require large initial outlays or that have long delays before benefits are realized."[33] First, we calculated net present values using a "social" or public discount rate of 3 percent. Second, we also calculated net present values using the opportunity cost of capital to private entities (at 7 percent).[34] These choices are described in more detail in the Appendix.

Since many GCA programs have characteristics that would suggest use of the public rate, yet others may suggest use of the private rate, we present results using the public rate in the body of this report, while noting the private rate results and providing further details in the Appendix.

Representation of Energy Efficiency Programs

A significant element of the GCA is the funding of investments in EE efficiency programs across Massachusetts. Programs included auditing and benchmarking efforts, investments in retrofit measures for existing homes (e.g., window and door treatments, insulation); residential lighting and appliance change-out (replacing refrigerators, washers, dryers or air conditioners with more efficient ones); commercial building shell, lighting, and equipment replacement; and new building measures (e.g., funding for more efficient materials and appliances at the time of new construction).

Given these various types of GCA-related EE activity, there were two major analytic challenges in the PROMOD modeling effort: First, we needed to determine an assumed duration or lifetime for savings from particular measures (for example, for how long does installation of insulation continue to produce savings?). Second, we needed to develop a way to map annual energy and peak load savings onto estimates of impacts on load in every hour of the year.

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[33] "Guidelines for Preparing Economic Analyses," U.S. Environmental Protection Agency, EPA 240-R-10-001, December 2010, page 6-5 (hereafter, "EPA Guidelines").

[34] EPA Guidelines, page 6-23.

Massachusetts M&V activities substantially document estimates of annual energy savings and contributions to reductions in peak loads. There is a long history of EE implementation and measurement and verification efforts to support engineering and statistical estimates of how the installation of a given EE measure actually translates into annual savings, distribution of savings across the hours of the year, and measure lifetimes. We relied on this literature to calculate the lifetime and load-impact characteristics of the various EE programs funded as a result of the GCA.

Where available, we reviewed on a program-by-program, measure-by-measure basis, the estimates of measure lives developed by states and utilities and currently used in programs, based on the past few decades' of experience in administering EE programs. We calculated weighted average measure life assumed by states and utilities across the range of measures, and found that virtually all programs have measure lives in excess of ten years. In our modeling, we conservatively truncated measure savings at ten years.

Utilities in Massachusetts provide estimates of how EE-related savings break down on a seasonal basis (summer or winter) and on a daily basis (on- or off-peak). Based upon a review of these estimates where available, we developed representative distributions of savings across seasonal and daily categories, and assigned annual energy savings to a given distribution on a program-by-program (and in some cases, measure-by-measure) basis.

Using these characterizations of EE program impacts, we calculated hourly adjustments to load for each EE program, and in aggregate for all programs used these to adjust hourly load in the PROMOD model.

4. RESULTS AND OBSERVATIONS

Overview

The first six years of GCA implementation leads to substantial changes in state and regional power system supply and dispatch, with related impacts on wholesale electricity prices, fuel mix, and emissions from the power generation sector. The GCA also involves spending by ratepayers to support investment in and installation of EE measures and programs, large quantities of BTM renewable resources within the state, and major quantities of grid-connected renewable resources throughout the Northeast.

This section summarizes how the GCA has changed the power system and what that means for the results of PROMOD power system dispatch analysis, and then summarizes results from the IMPLAN macroeconomic analysis.

Power System Impacts

The GCA has significantly altered the overall level of demand in the New England region, and how resources are added to the system over time. Table 1 demonstrates overall reduction in annual energy consumption over the modeling period, as well as lowered peak demand, for Massachusetts and the region. Once fully implemented, the first six years of GCA programs reduce total annual energy consumed in Massachusetts by up to 3.6 TWh. Peak summer demand is reduced by 614 MW.[35]

The impact on generation in the region and in Massachusetts is also significant. The implementation of GCA programs leads to substantial additions of renewable generating capacity, and reductions of fossil-fueled generating capacity. See Figure 5. By 2025, GCA programs lead incrementally to the addition in New England of more than 2,800 MW of renewable capacity (including over 2,000 MW of wind and over 700 MW of solar PV), reducing the need for more than 700 MW of gas-fired generating capacity.

GCA programs also impact annual power production in New England: traditional fossil generation is reduced by nearly 69 TWh, and generation from new renewable resources increases by approximately 55 TWh. See Figure 6. As can be seen in Table 2, within Massachusetts there is a substantial tradeoff between renewable and fossil generation. Finally, Figures 7A and 7B show how GCA reduces consumption of coal and natural gas within New England on an annual and cumulative basis.

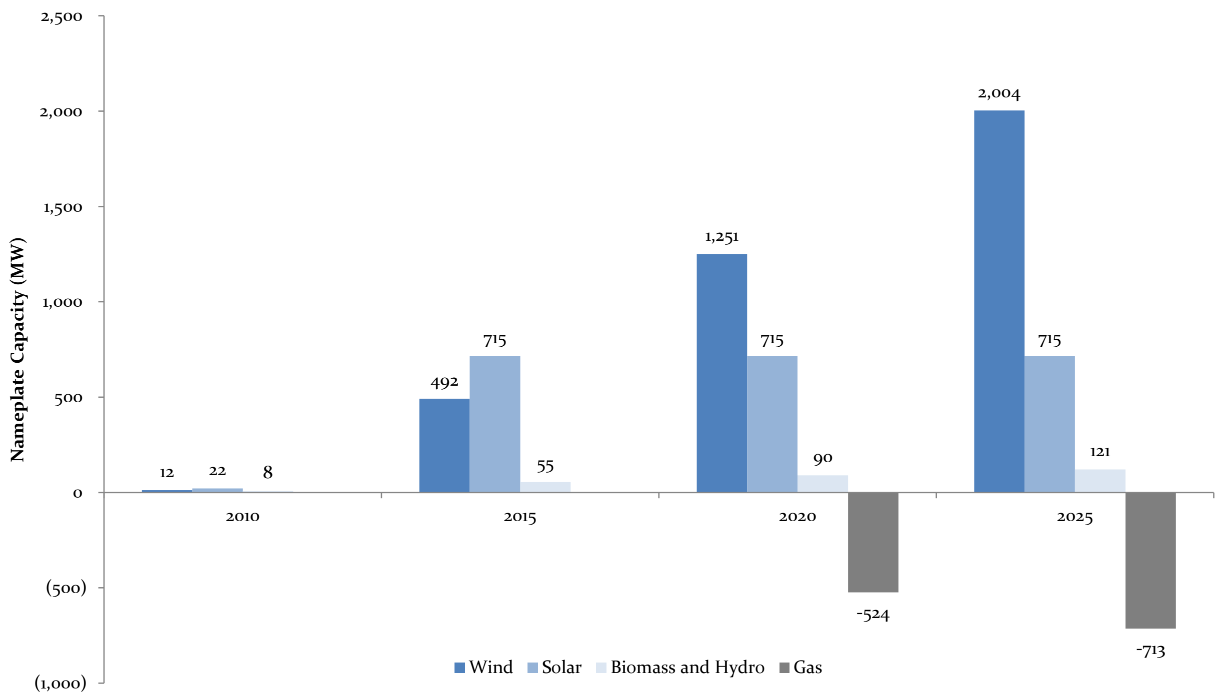
[35] As can be seen in Table 1, the total annual energy and peak load reductions increase as EE and renewable installations increase, and then decrease in later years. This is an artifact of how we constructed the model (to look at implementation of only the first six years) and the decision to truncate energy savings from measures and programs at year 10. In reality, to the extent GCA programs continue beyond year six, and EE savings continue beyond 10 years, the actual annual energy and peak load savings would continue to grow.

Table 1
Peak and Total Energy Demand in Massachusetts
With and Without the Green Communities Act
2010-2025

	Massachusetts					
	With GCA		Without GCA		Difference	
Year	Peak (MW)	Total Energy (GWh)	Peak (MW)	Total Energy (GWh)	Peak (MW)	Total Energy (GWh)
2010	12,556	59,618	12,570	59,705	(14)	(87)
2011	12,891	58,860	12,945	59,188	(54)	(329)
2012	12,277	58,317	12,407	59,085	(130)	(768)
2013	12,219	59,108	12,466	60,567	(247)	(1,459)
2014	12,290	59,313	12,677	61,605	(387)	(2,292)
2015	12,454	59,462	12,983	62,630	(529)	(3,168)
2016	12,678	59,909	13,292	63,527	(614)	(3,617)
2017	12,772	59,877	13,393	63,494	(621)	(3,617)
2018	12,843	59,809	13,472	63,427	(629)	(3,617)
2019	12,916	59,711	13,545	63,329	(629)	(3,617)
2020	12,981	59,636	13,574	63,166	(593)	(3,530)
2021	13,059	59,585	13,612	62,874	(553)	(3,289)
2022	13,122	59,562	13,610	62,411	(488)	(2,849)
2023	13,193	59,501	13,570	61,659	(377)	(2,159)
2024	13,265	59,440	13,502	60,765	(237)	(1,325)
2025	13,335	59,379	13,415	59,828	(80)	(449)

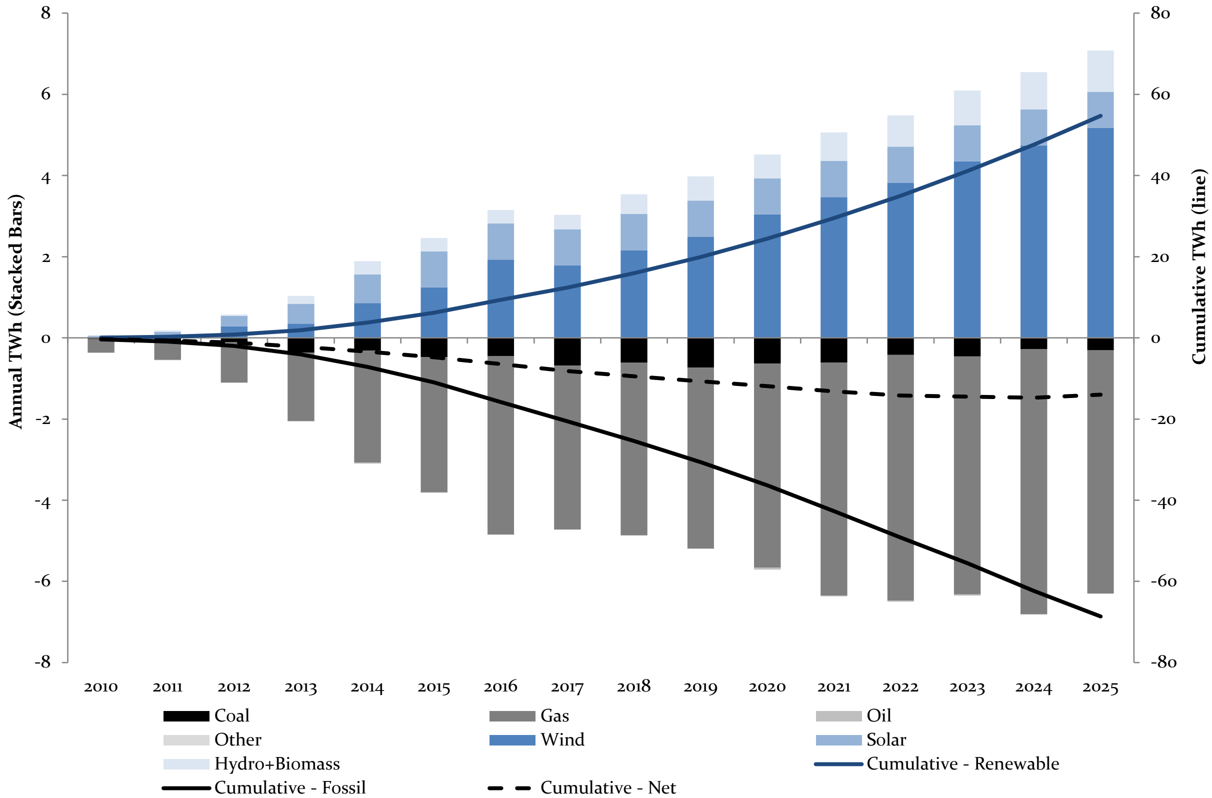
	ISO-NE					
	With GCA		Without GCA		Difference	
Year	Peak (MW)	Total Energy (GWh)	Peak (MW)	Total Energy (GWh)	Peak (MW)	Total Energy (GWh)
2010	26,705	128,780	26,719	128,867	(14)	(87)
2011	27,334	126,970	27,388	127,299	(54)	(329)
2012	25,553	126,043	25,683	126,811	(130)	(768)
2013	26,610	130,404	26,857	131,863	(247)	(1,459)
2014	26,854	131,030	27,241	133,322	(387)	(2,292)
2015	27,213	131,831	27,742	134,999	(529)	(3,168)
2016	27,751	133,279	28,365	136,897	(614)	(3,617)
2017	27,971	133,425	28,592	137,042	(621)	(3,617)
2018	28,135	133,456	28,764	137,073	(629)	(3,617)
2019	28,303	133,426	28,931	137,044	(629)	(3,617)
2020	28,460	133,427	29,053	136,957	(593)	(3,530)
2021	28,638	133,484	29,191	136,773	(553)	(3,289)
2022	28,788	133,599	29,276	136,448	(488)	(2,849)
2023	28,952	133,638	29,329	135,797	(377)	(2,159)
2024	29,115	133,678	29,353	135,003	(237)	(1,325)
2025	29,287	133,720	29,367	134,169	(80)	(449)

Figure 5
Cumulative Capacity Additions in New England due to GCA
Nameplate Capacity (MW), 2010-2025



<u>**Notes**</u>:
[1] Nameplate capacity does not represent the seasonal claimed capability (SCC), which is the basis for capacity market and resource adequacy determinations. For the purposes of this study, additions of nameplate capacity were derated to summer SCC on a technology basis.
[2] Units are added as capacity at the end of the year before they come in-service and generate energy. Thus data shown in 2020 represents units operating in 2021.

Figure 6
Cumulative and Annual Differences in New England Generation due to GCA by Resource Type, 2010-2025



Note:
[1] Units are added as capacity in the year before they come in-service and generate energy.

Table 2
Annual Differences in Massachusetts Generation (MWh) due to GCA by Fuel Type, 2010-2025

Year	Coal	Gas	Nuclear	Oil	Hydro	Wind	Solar	Biomass	Other	Total
2010	-15,975	-128,970	0	-373	-11,455	20,459	23,687	39,585	0	-73,043
2011	-41,008	-219,937	0	-201	-6,290	77,276	68,860	47,216	0	-74,083
2012	-79,585	-463,887	0	0	-18,533	181,722	253,613	56,581	-17	-70,106
2013	-299,960	-799,250	0	0	2,619	252,308	489,632	193,048	-39	-161,641
2014	-214,901	-1,377,085	0	-21,957	-19,437	285,295	703,540	289,443	-35	-355,137
2015	-296,782	-1,462,040	0	-10,692	-29,770	283,199	891,171	289,443	-72	-335,543
2016	-293,371	-2,196,390	0	0	-45,211	828,955	891,255	290,236	-76	-524,603
2017	-477,685	-2,180,014	0	0	-57,256	1,273,752	889,719	289,443	-81	-262,123
2018	-353,703	-2,093,823	0	0	-32,949	1,245,550	889,719	289,443	-75	-55,837
2019	-462,921	-2,246,824	0	-5,413	-5,939	1,251,537	889,719	289,443	-108	-290,507
2020	-430,342	-2,532,663	0	-35,700	-78,393	1,292,137	891,255	290,236	-130	-603,601
2021	-447,247	-2,638,570	0	-17,879	-11,267	1,264,877	889,719	289,443	-72	-670,996
2022	-256,487	-2,890,448	0	-22,506	110	1,271,189	889,719	289,443	-90	-719,070
2023	-231,959	-2,724,814	0	-23,426	32,707	1,285,566	889,719	289,443	-76	-482,840
2024	-174,899	-2,945,309	0	-4,089	40,369	1,258,348	891,255	290,236	-97	-644,187
2025	-159,392	-2,593,137	0	4,039	89,075	1,278,823	889,719	289,443	-103	-201,534

Figure 7A
Coal Consumption Reductions in New England due to GCA in MMBtu, 2010-2025

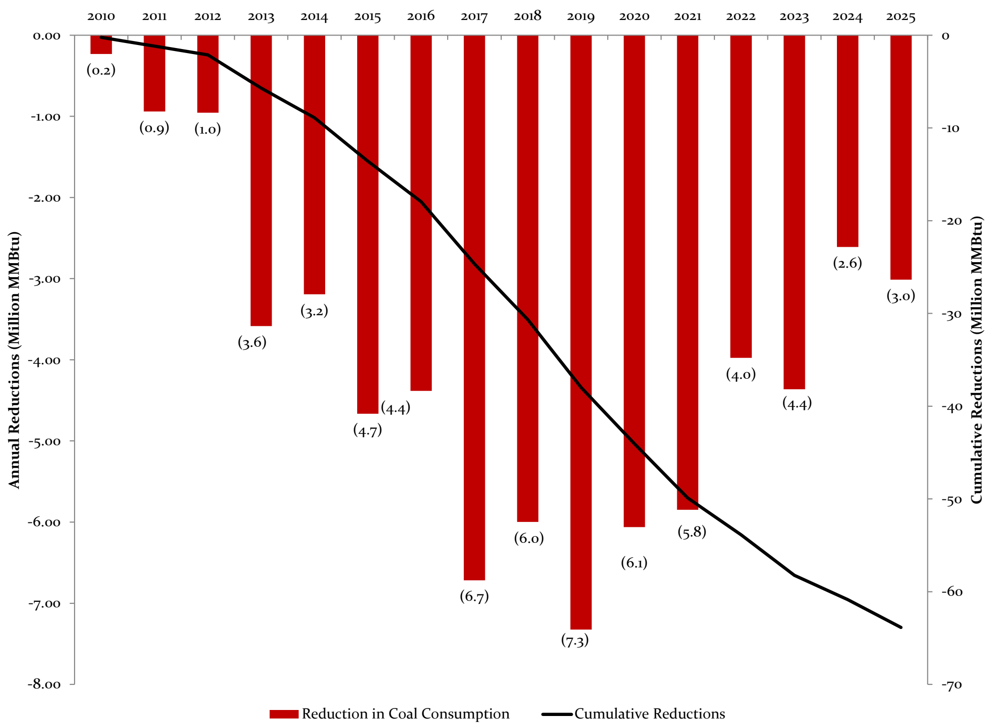
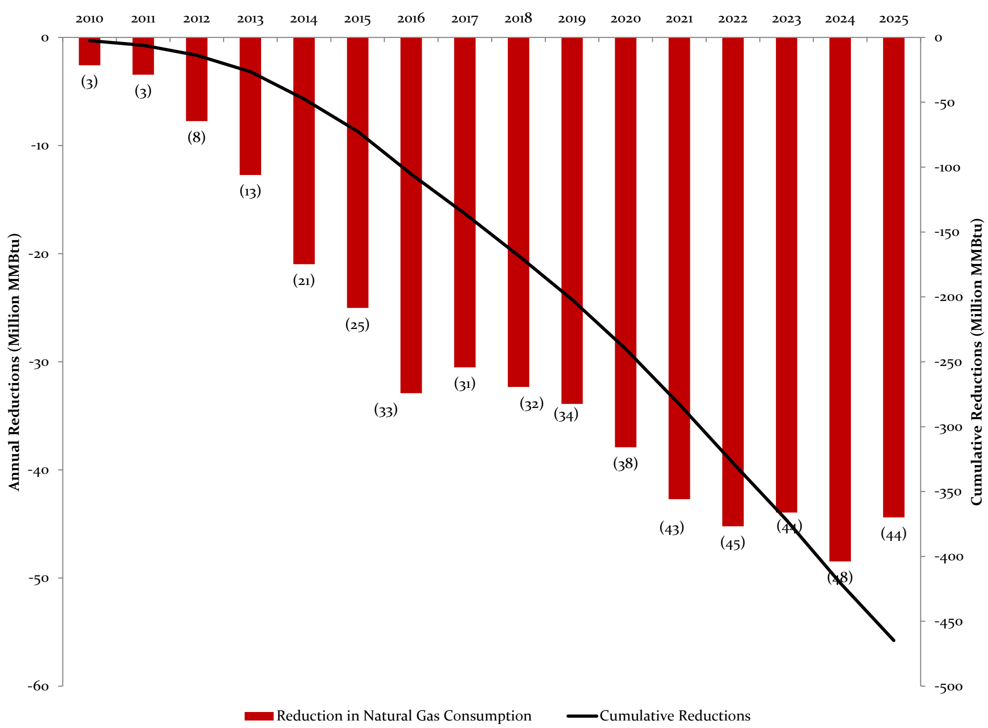


Figure 7B
Natural Gas Consumption Reductions in New England due to GCA in MMBtu, 2010-2025



Changes of this magnitude in total demand, consumption, and low variable cost renewable generation have long-lived price suppression effects in wholesale markets. As can be seen in Figure 8, at the peak of assumed EE savings in 2020, wholesale prices are reduced in Massachusetts by approximately $2.50/MWh. These impacts affect consumers in Massachusetts and in the rest of New England.

Finally, the tradeoff of traditional fossil fuel generation for new (primarily) wind and solar generation comes with a predictable benefit in the form of lower air-pollution emissions associated with meeting the region's electricity needs. Figure 9 shows annual and cumulative reductions in emissions of CO2 due to implementation of the GCA. CO2 reductions peak at approximately 2.8 million metric tons in 2021; on a cumulative basis emissions are reduced by almost 31 million metric tons over the study period (for context, the total 2014 annual cap on CO2 emissions in the nine-state Regional Greenhouse Gas Initiative is 91 million metric tons[36]). Similar reductions over the study period occur for Hg, NO_x, and sulfur dioxide SO_2. As a result of the GCA, Hg emissions decline by 165 lbs, NO_x emissions decline by 23.2 million lbs, and SO_2 emissions decline by 38.3 million pounds.[37]

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[36] RGGI, Summary of Model Rule Changes, February 2013.

[37] Note that three of these pollutants are controlled across most of the states included in the power systems of the Northeast U.S. through regional or nation-wide caps on emissions, with full trading of allocated or purchased allowances. Consequently, estimated "reductions" in emissions modeled in the study may over time lead to reduced costs of compliance (compared to the no-GCA case) rather than an absolute reduction in the number of tons emitted.

Figure 8
Wholesale Electric Price Reductions due to GCA in $/MWh LMPs, 2010-2025

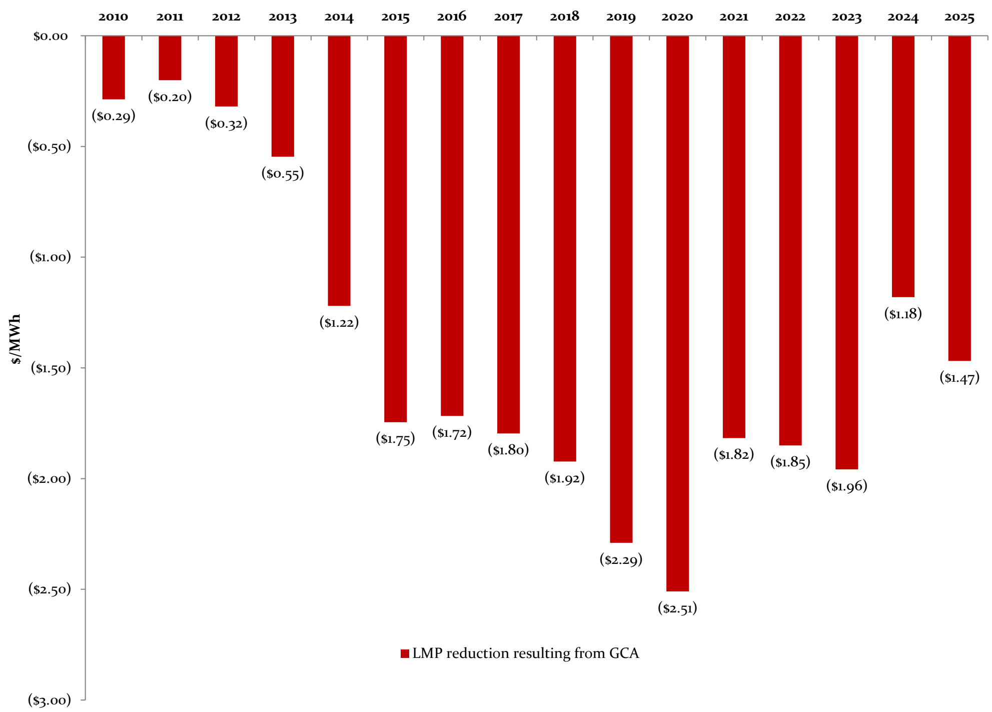
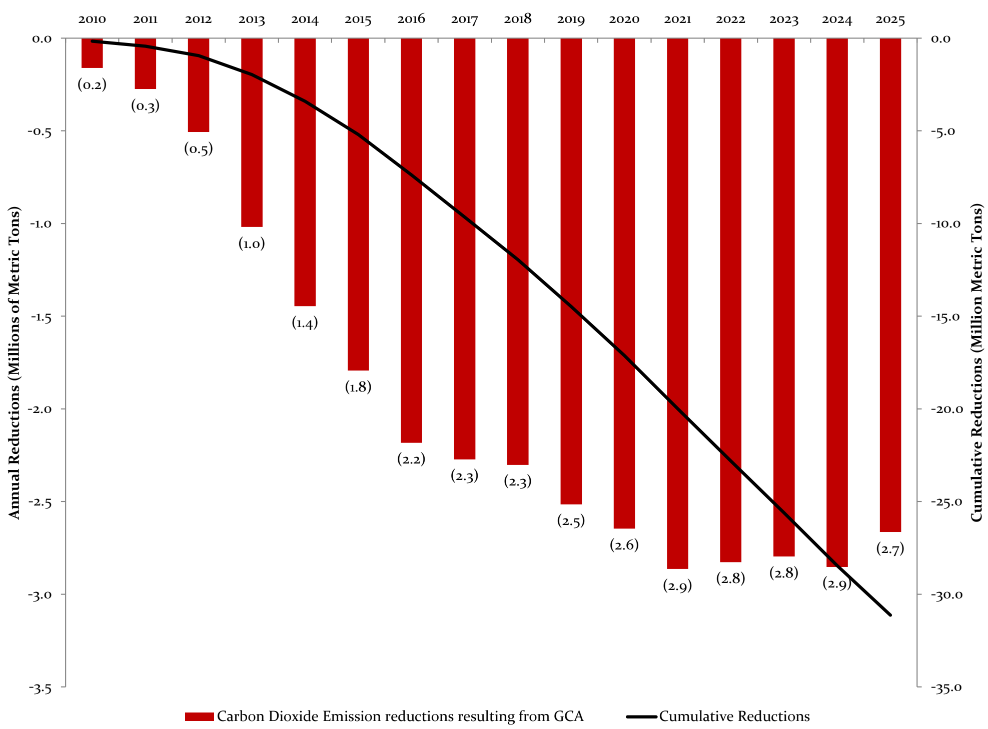


Figure 9
Carbon Dioxide Emission Reductions in New England due to GCA in Metric Tons, 2010-2025



Economic Impacts

The results of the economic modeling of the GCA are presented in Table 3. Our analysis finds that the first six years of GCA implementation leads to $1.2 billion (in 2013 net present value dollars) in net economic benefits to Massachusetts, and more than 16 thousand jobs.[38] The $1.2 billion also includes state and local tax revenues of roughly $155 million.[39] This represents only monetary impacts in Massachusetts. Non-monetary costs and benefits inside Massachusetts, and all costs and benefits occurring outside the state are not calculated.

In addition, we analyzed results across a range of the key sensitivity from a power system perspective – namely the price of natural gas. Benefits are sensitive to assumptions about natural gas prices (which affects the value of programs that lower gas consumption for direct use and for electricity generation). If gas prices are 30 percent higher than assumed, benefits increase to almost $1.8 billion, with 21 thousand jobs added.[40] If gas prices are 30 percent lower, benefits are reduced to approximately $0.6 billion.[41]

Table 3
Massachusetts Economic Value Added and Jobs Created as a Result of the GCA
(Reflecting Base Case and Alternative Scenarios
Discounted at Private and Public Discount Rates)

Description	3% Discount Rate		7% Discount Rate	
	Value Added*	Jobs**	Value Added*	Jobs**
Base Scenario	$1.17 billion	16,395	$0.63 billion	16,395
High Gas Price (+30%)	$1.80 billion	21,651	$1.13 billion	21,651
Low Gas Price (-30%)	$0.60 billion	11,781	$0.18 billion	11,781

"Economic Value Added" reflects the total economic value added to the economy, which reflects the gross economic output of the area less the cost of the inputs. The reported numbers reflect net present value of economic value added. "*Jobs*" reflect the number of full-time job years over time, and are not discounted.

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[38] This is based on a "public" discount rate of 3%. Using a 7% "private" discount rate the benefits are on the order of $0.6 billion. Job numbers equal "job years," reflecting both the number of jobs created and the length of those jobs.

[39] This is based on a "public" discount rate of 3%. Using a 7% "private" discount rate the tax revenues are on the order of $113 million.

[40] This is based on a "public" discount rate of 3%. Using a 7% "private" discount rate the benefits are slightly over $1.1 billion.

[41] This is based on a "public" discount rate of 3%. Using a 7% "private" discount rate the benefits are slightly under $0.2 billion.

APPENDIX

Analytic Method, Data Sources and Assumptions

Electric System Model Overview: Ventyx PROMOD

Our analysis of economic impacts of the Green Communities Act on the power system used Ventyx's PROMOD model. This is a proprietary electric system dispatch model that simulates the operation of an interconnected utility power system, taking into account constraints on the operation of the grid.

PROMOD is particularly helpful in modeling the dispatch of the New England wholesale power market because the model is configured in ways that align with the operations and market design in that power market, as well as the surrounding markets of New York and eastern Canada. PROMOD comprehensively simulates the economic dispatch of the power system on an hourly basis based on each power plant's operational characteristics and marginal production costs, subject to various operational and transmission system constraints that can alter dispatch order (and thus prices) in real time. PROMOD also uses algorithms designed to reflect the operational constraints of power plants, such as the time it takes to start units, to ramp them up and down to various power levels, the minimum time they must be on, and the minimum time they must be off.

Given the level of detail in how PROMOD represents the power system – that is, down to very small power plants and specific transmission system components and limits – the model allows the user to simulate a power system's operations on an hour-by-hour basis and with a high degree of geographic resolution. Results include individual power plants' unit output and emissions, power prices, consumers' payments for electric energy, and power plant producer revenues in electric energy markets.

To calculate the impacts of the GCA on power system operations and outcomes, we used PROMOD to simulate the "with GCA" and "without GCA" systems that serve New England, New York, and eastern Canada, with the difference between the two simulations being the direct incremental impacts of the GCA on the power system. These two simulations otherwise maintained the same inputs, in terms of fuel prices, power plant operational characteristics, emissions allowance costs, baseline load levels, and so forth. Several core assumptions (e.g., load levels that change as a result of energy efficiency investments, addition of renewable resources attributable to the GCA) were changed, and the model re-run to simulate the "without GCA" case. As described in the body of the report, the simulation period is the historical 2010-2012 period, the 2013-2015 period during which programs outlined in the second approved GCA three-year plan for energy efficiency will be implemented, and a 10-year tail period (through 2025) to capture the useful life of energy efficiency measures implemented through the GCA

Electric System Model Data and Assumptions

Fuel Prices in the Power Sector

Natural Gas

For the modeling period from January 2010 through November 2013, natural gas prices are based on historical spot prices at regional hubs. From December 2013 through December 2025 natural gas prices were calculated as the Henry Hub base price estimated from futures contracts plus the historical regional Hub basis differentials between Henry Hub and the relevant Northeast region.

- From January 2010 through November of 2013 natural gas prices: in New England gas prices were calculated as the monthly average of daily spot prices at the Algonquin Citygate, Tennessee Zone 6, and Dracut pricing hubs; gas prices in New York were calculated as a monthly average of daily spot prices at the Niagara and Transco Zone 6 NY pricing hubs; and gas prices in eastern Canada were calculated as a monthly average of daily spot prices at the Dawn – Ontario pricing hub.
- From December of 2013 through December of 2025 the base Henry Hub price is based on NYMEX futures prices. To capture the delivered price of natural gas into the region of interest, we added to the base Henry Hub price a basis differential based on historical differences between prices at Henry Hub and those within each region based on three-year averages of basis differentials in each month of the year.

Distillate Oil

From January 2010 through December 2025, distillate prices are based on annual prices as provided in the 2013 EIA AEO Electric Power Projects for EMM Region, Northeast Power Coordinating Council/Northeast, Reference case.

Residual Oil

From January 2010 through December 2025, residual prices are based on annual prices as provided in the 2013 EIA AEO Electric Power Projects for EMM Region, Northeast Power Coordinating Council/Northeast, Reference case.

Coal

Coal prices are the default prices contained in Ventyx PROMOD Simulation Ready Data, using the default escalation factors contained therein.

Power Plants: Existing Units, Unit Retirements and Additions

Starting with the default PROMOD generator data set (the current and planned actual plants operating within eastern Canada, New York, and New England), we made changes to reflect unit retirements and power plant additions as appropriate for the "with GCA" and "without GCA" cases. Unit retirement decisions for the study area are based on assumed retirements in the Ventyx generator dataset. Unit retirements within New England were also updated, consistent with the non-price generator retirement notices for the 2017-2018 Capacity Commitment Period, based on the accepted ISO-NE status of these retirements as of November 2013. Unit additions were included for new generators from the 2016-2017 Forward Capacity Auction.

Renewables

Renewable electric resources were added to meet the cumulative ISO-NE Renewable Portfolio Standard (RPS) targets from each state, based on the 2012 Renewable Portfolio Standards Spreadsheet from the ISO-NE Environmental Advisory Group.[42] This included RPS targets for 2012 through 2025.[43]

For the "with GCA" scenario, this included two steps.

- First, wind resources were added to the PROMOD generator database from identified Massachusetts utility long-term contracts and net metering installations. Solar additions were added in quantities consistent with identified utility solar programs and net metering capacities from the MassACA.[44]
- Second, the additional RPS target MWh were assumed to be met through incremental wind, hydro, and biomass additions in proportions equal to the observed ratios of those same sources in the November 2013 ISO-NE Interconnection Queue.[45] Energy quantities from installed capacity additions were estimated using the technology specific capacity factors from the Brattle Group ORTP[46] update commissioned by ISO-NE. Wind resources were added at existing locations in Maine, New Hampshire and Vermont, in proportions consistent with the November ISO-NE interconnection queue. Biomass facilities were placed at existing hubs in New Hampshire and hydro additions were added as expansions to existing units in Maine. Cape Wind was included in the "with GCA" case and modeled with an in-service data of 2016.

For the "without GCA" case, renewable resources were added in the same manner, with three changes.

- First, we assumed that absent the GCA, the Class I RPS target for Massachusetts would remain at the 2009 level. Therefore, all renewables located in Massachusetts with an in-service date of 2010, 2011, 2012, or 2013 were removed from PROMOD.
- Second, the quantity of imported renewable MWh used to meet the MA RPS standard in 2010-2012 was identified from the 2011 RPS Compliance report.[47] These MWh were removed from New York and Eastern Canada, consistent with the actual proportion of imports.
- Third, the long-term contracts, utility solar additions, and net metering additions from the "with GCA" scenario were excluded.

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[42] Available at: http://www.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/eag/usr_sprdshts/index.html

[43] We assumed that default PROMOD generator data included all renewables installed to meet the current 2010-2013 RPS targets.

[44] Available at: http://www.massaca.org/default.asp

[45] This assumes that wind projects account for 89.7 percent of the identified need, hydro for 2.9 percent, and biomass for the remaining 7.4 percent.

[46] ORTP = Offer Review Trigger Price, which are used by ISO-NE to administer the forward capacity market's minimum offer price rule. This includes a default 35 percent capacity factor for wind and a 14 percent capacity factor for solar.

[47] 2012 totals were estimated from the 2011 using the average growth rate between 2010 and 2011.

Generic Capacity Additions to Meet Resource Adequacy

After the incremental addition of renewable capacity and retirement of units discussed above, we analyzed the extent to which ISO-NE's summer seasonal capacity (SCC) satisfied forecasted resource adequacy requirements in each year, assuming a 15 percent reserve margin above forecasted peak demand.[48] This review determined that additional resources were required beginning in 2021 in the "without GCA" scenario and in 2025 in the "with GCA" scenario. New capacity was added in the quantities necessary to meet forward-looking three-year needs. Thus, in the "without GCA" scenario, 525 MW were added in 2021 to meet the 2023 resource need, and an additional 365 MW were added in 2024 to meet the remaining need through the end of the study period. In the "with GCA" scenario, 177 MW was added in 2025 only.

New capacity was added in equal quantities for natural gas combined cycle and gas turbine plants. This capacity was added in equal amounts within Massachusetts and Connecticut consistent with the November 2013 ISO-NE interconnection queue. New units were modeled with heat rates and start up energy costs consistent with recently built natural gas generating plants.

Outages

PROMOD generated a random pattern of generator maintenance and forced outages for each year of the study. The same outage pattern was used for both the "with GCA" and "without GCA" cases.

Emissions costs

Emissions prices reflect Ventyx Simulation Ready Data defaults and were not altered. These include RGGI program CO_2 allowance costs, as well as NO_x and SO_2 allowance costs.

Load Profiles

Historical information about actual customer loads and long-term forecast values for load and energy were obtained for the 2010-2012 period from the latest ISO-NE load forecast documentation.

Target energy and peak load (net of passive demand resources) forecasts were obtained from ISO-NE's 2013 CELT Report. Because ISO-NE only forecasts data through 2022, load and total energy were grown at the 2018-2022 total energy growth rate to compute values through 2025.

For the "with GCA" case, actual historical ISO-NE hourly load data were used for the years 2010 – 2012. These data were aggregated in each hour at the state level, and then distributed out to each of the 13 PROMOD sub-areas that comprise New England based on the ratio of Annual Energy Net PDR for 2013 in the 2013 ISO-NE CELT forecast. For 2013 – 2025, "with GCA" case load forecasts were generated within PROMOD using peak and total energy forecasts from the 2013

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[48] We performed a calculation using generator data from PROMOD and generator information from the 2013 ISO-NE CELT report and calculated the average ratio of summer SCC to nameplate capacity for each technology. These derate values were used to translate resource adequacy needs on a SCC basis into nameplate additions for PROMOD.

ISO-NE CELT report and Ventyx load shapes for each sub-area, which are based on an average of 2003- 2011 data.

The Massachusetts sub-area load profiles were modified in the "without GCA" case to exclude the load reduction impact of the GCA. Actual electric savings from gas and electric energy efficiency programs were identified from the first three year utility program administrator plans and forecasted savings were identified from the second three year utility plans. In each year, these annual energy savings were adjusted to exclude actual 2009 baseline energy savings and the proportion of annual savings due to programs funded by RGGI proceeds. Annual GCA energy efficiency impacts were allocated to summer and winter peak and off-peak periods consistent with the ratio of savings from the program administrator data. These MA energy savings were allocated to the four PROMOD sub-regions for Massachusetts (Boston, CMA-NEMA, SEMA, and WMA) based on the ratio of total annual energy in each sub-area in each year and spread equally across all hours of each period. Energy savings from each year were assumed to be in effect for 10 years, with one-half of the annual savings realized in the same year as reported in the program administrator data and the second half coming online in the following year. The cumulative impact of these changes is a maximum 629 MW change in Massachusetts peak summer demand in 2018 and 2019 and a total energy addition of 3,617 GWh in each year 2016 through 2019.

The default PROMOD load profiles were used for regions outside of ISO-NE.

Macroeconomic Model Overview: IMPLAN

Our analysis of macroeconomic impacts of the Massachusetts GCA used IMPLAN. IMPLAN (which stands for "IMpact analysis for PLANning") is a social accounting/input-output model that attempts to replicate the structure and functioning of a specific economic area. IMPLAN is widely used for economic impact assessments in the public and private sectors.[49]

Input/output (I/O) models are based on long-standing, well-established and broadly accepted methodologies designed to estimate the impacts on a regional economy of a change in economic activity. Such models are based on a methodology established decades ago by economists for tracking the effects on changes in the inputs or outputs of an industry (or some other segments of an economy) as they ripple through the economy.

The broad conventional approach to examining these economic flows is to rely on national economic I/O account survey data. These data are based on census information collected from businesses that track the flows of dollars into and out of enterprises. The data make up the basis for the input/output tables that reflect the movement of dollars within an economy and the multiplier effects that reflect the role of dollars in influencing different multiplier effects in different segments of economies. The Bureau of Economic Analysis within the U.S. Department of Commerce collects information related to these relationships among different segments of regional economies. Over the years, these economic accounts are verified and serve as the basis for a wide variety of macroeconomic metrics (such as Gross Domestic Product, Gross State Product, and countless other economic variables).

The IMPLAN model allows one to investigate various interactions in a defined economy (in this case, the state of Massachusetts) and to calculate various economic impacts in that economy when a new activity (such as investments in energy efficiency or the cost to consumers of such programs) involves money flows around the economy.

IMPLAN relies on a detailed system of accounting for relationships among different parts of the economy, and relies on national economic data for the specified region. The model tracks dollars spent in a region, including dollars that circulate within it (e.g., transfers of dollars from consumers to producers), dollars that flow into it (purchases of goods and services from outside the local economy), and dollars that flow outside of it (e.g., payments to the federal government; purchases of goods and services produced outside of the area). The model thus examines inflows, outflows, and interactions within the economy under study.

Specifically, the model captures various effects, including:

- *Employment effects* (the total number of jobs created or lost);
- *Income effects* (the total change in income to employees that results from the economic activity); and
- *"Value-added" effects* (the total economic value added to the economy, which reflects the gross economic output of the area less the cost of the inputs).

[49] Complete information on IMPLAN can be found on its website, implan.com.

In our analysis, we focused on added value, since this is the overall measure of change in macroeconomic activity.

There are various ways in which the new activity creates impacts, each of which is separately tracked by the model. More specifically, the effects are:

- *Direct effects*: The set of expenditures applied to the predictive model (i.e., I/O multipliers) for impact analysis. It is a series of (or single) production changes or expenditures made by producers/consumers as a result of an activity or policy. These initial changes are determined to be a result of this activity or policy. Applying these initial changes to the multipliers in an IMPLAN model will then display how the region will respond, economically, to these initial changes.
- *Indirect effects*: The impact of local industries buying goods and services from other local industries. The cycle of spending works its way backward through the supply chain until all money leaks from the local economy, either through imports or by payments to value added.
- *Induced effects*: The response by an economy to an initial change (direct effect) that occurs through re-spending of income received by a component of value added. IMPLAN's default multiplier recognizes that labor income (employee compensation and proprietor income components of value added) is not a leakage out of the regional economy. This money is recirculated through the household spending patterns causing further local economic activity.

Direct effects are determined by an "Event" as defined by the user (i.e., a $1 million dollar purchase of insulation is a $1 million dollar direct effect; a $1 million dollar expenditure on installation of solar panels is a different $1 million dollar direct event).[50] The indirect effects are determined by the amount of the direct effect spent within the study region on supplies, services, labor and taxes. Finally the induced effect measures the money that is re-spent in the study area as a result of spending from the indirect effect. Each of these steps recognizes an important leakage from the economic study region spent on purchases outside of the defined area. Eventually these leakages will stop the cycle.

State Economic Database

Our IMPLAN analysis of the GCA was based on the most recent state data file (2012) for Massachusetts. This state-level data file includes information for a set of highly disaggregated industries, sorted generally by their 4- and 5-digit NAICS codes.[51]

IMPLAN data files are compiled from a wide variety of sources including the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor, and the U.S. Census.[52] They include information

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[50] Note that analyzing the economic value added means that a dollar of direct spending does not translate into a direct effect of one dollar of value added. For example, if a dollar is spent in state on light bulbs, the direct value added is only the net revenue and income of the retail store where the light bulb was purchased, thus excluding the manufacturing costs of the light bulb itself.

[51] NAICS codes are tied to the North American Industry Classification System, which is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy.

[52] The IMPLAN data files use federal government data sources including the following federal programs: Bureau of Economic Analysis Benchmark I/O Accounts of the US and Output Estimates; Bureau of Labor Statistics Covered Employment and Wages (ES202)

about regional employment, income, value-added, household and government consumption. Examples include: employee compensation; proprietary income; federal, state and local taxes affecting income, sales, real estate, and so forth; personal consumption expenditures at nine income levels; federal government purchases (military and non-military) and investments; purchases by local and state governments (including educational institutions); inventory purchases; capital formation; foreign exports; and inter-institutional transfers. They also include unique national I/O structural matrices and unique annual trade flow models.

Expenditure Categories Used in IMPLAN Modeling

In our IMPLAN analysis, we assigned expenditures into a variety of IMPLAN sector categories, based on assumptions about the character of the economic activity tied to each particular category.

For example, different types of expenditures on energy efficiency end up with different economic effects, and we modeled them in various ways to capture these differences. For example, we modeled expenditures to buy energy-efficient appliances as purchases at retail stores for electronics and appliances. We modeled spending on residential lighting as a combination of maintenance and repair construction of residential structures, along with purchases at retail stores for building materials. We modeled energy efficiency measures in residential buildings as construction of new residential buildings, single and multi-family structures, and those in commercial buildings as construction of other new non-residential structures.

We modeled spending on on-site renewable energy equipment also as construction of other new non-residential structures. Other non-energy efficiency examples include GCA-related expenditures on: education and outreach programs (modeled as other private educational services); consumer bill reductions (modeled based on IMPLAN's designation of electricity spending across all other sectors); revenue losses to power plant owners (modeled as electric power generation, transmission, and distribution); and in-state loans from commercial banks for installation and construction of renewable generation (modeled as commercial banking activities).

Macroeconomic Model Data and Assumptions

Electric Consumer Impacts

Changes in consumers' payments for electric energy came directly from the PROMOD electric system modeling output. Changes in their payments of capacity-related electricity costs reflect the difference between the "business as usual" capacity market price compared with the cost of new entry (CONE) in years where our resource-adequacy analysis identified the need for new resources. The "business as usual" clearing price was based on an analysis performed for ISO-NE

Program and Consumer Expenditure Survey; Census Bureau County Business Patterns, Decennial Census and Population Surveys, Censuses and Surveys; Department of Agriculture Crop and Livestock Statistics; and US Geological Survey.

related to its proposed forward capacity market redesign. CONE was based on the Brattle Group's updated ORTP analysis performed for ISO-NE. Both prices were inflated from the reported prices by an inflation factor based on the year in which there was a difference in resource adequacy in the GCA versus no-GCA cases. This difference in clearing price was multiplied by the Massachusetts portion of peak load as forecasted by ISO-NE in the year the difference occurs. These same values for CONE were used to calculate the construction costs of the new capacity that was identified, which were modeled as being spent over a three-year period for the purposes of IMPLAN modeling of the construction impacts.

Non-electric consumer cost differences came from state utility filings reporting natural gas savings by year for the period 2010-2015. These savings were compared with the 2009 baseline savings totals, with the difference representing the incremental effect of the GCA increase in spending on non-electric programs. This cumulative total in each year was multiplied by the annual average natural gas price in that year.

Energy efficiency program cost differences (both electric and non-electric) came from state utility filings reporting electric savings and expenditures by year for the period 2010-2015. These expenditures were compared with the 2009 expenditure totals, with the difference representing the incremental effect of the GCA increase in spending on energy efficiency programs. Costs to consumers also reflect expenditures in the Massachusetts economy (i.e., electric consumer costs for energy efficiency retrofits equal construction and installation expenditures to retrofit homes and businesses, prior to the macroeconomic multiplier effects).

Utility-constructed solar facilities and costs came from state utility filings.

Payments for renewable energy credit (REC) reflect the difference between the current Class I and Alternative Portfolio Standard (APS) REC requirements and the 2009 baseline level of Class I REC requirements. Subtracted from this difference is the generation resulting from net metering installations, utility-constructed solar facilities, and long-term renewable contracts. This net difference is multiplied by the forecasted REC price in Massachusetts, which is assumed to equal the historical average of the monthly prices from 2010-2013 identified by the US Department of Energy and sourced to Marex Spectron.

Additional electric consumer impacts are also detailed in the net metering and Cape Wind sub-sections, below.

Electric Supplier Impacts

The impacts on power plants located in Massachusetts and owned by Massachusetts companies come in the form of changes in revenues between the with-GCA case and the without-GCA case. These electric supplier net revenue differences for electric energy generation came directly from the PROMOD electric system modeling output. For the capacity market, these were calculated using the same prices as detailed in the electric consumer impacts sub-section above. These prices were multiplied by the capacity of Massachusetts owned generation assets in the with-GCA and without-GCA cases.

Electric supplier net revenue from the Massachusetts APS was calculated by multiplying the REC prices (described in the electric consumer impacts sub-section above) by the APS REC requirements. These revenues were assumed to be solely earned by Massachusetts companies based on a review of the most recent Massachusetts Department of Energy Resources Annual Compliance Report for Massachusetts' RPS and APS.

Net-Metering Installations

Solar and wind installations driven by net-metering policy were based on the Massachusetts System of Assurance of Net Metering Eligibility. We assumed that build-outs of projects would hit the net-metering caps by the end of 2015. Installation costs for solar reflect costs as reported in the Massachusetts Department of Energy Resources listing of all solar installations in the state. Installation costs for wind reflect costs as calculated by the Brattle Group's updated ORTP analysis for ISO-NE. Construction impacts in Massachusetts reflect all in-state expenditures from above, which remove material (e.g. solar panels) costs using the National Renewable Energy Laboratory's (NREL) JEDI model for solar PV and onshore wind.

Cape Wind and Other Long-Term Renewable Contracts

Contract costs for Cape Wind were based on National Grid's Cape Wind filings, and scaled to include NSTAR's contracted portion of Cape Wind's capacity. Additional costs and revenues include remuneration to National Grid and NSTAR. Profits were assumed to be 10.75 percent of the total contract cost, with 50 percent of profits assumed to flow to Massachusetts shareholders. 4 percent of the contract cost was assumed to be financed, with 25 percent assumed to be financed by Massachusetts banks. The 22.5 percent of Cape Wind's output that is not under contract was assumed to generate revenues equal to construction costs. Construction expenditures in Massachusetts were based on the NREL JEDI model for offshore wind, using the local share of spending reflected in NREL's model (e.g., manufacturing for components such as turbines is assumed to be out of state).

Long-term renewable contracts (other than Cape Wind) that have already been approved and found by regulators to have below-market prices were assumed not to lead to further incremental costs above the regular price of electricity.

Discount Rate Overview

Our analysis involves the assessment of spending and costs that occur in different periods of time. The study examines the flow of dollars beginning in 2010 when the GCA took effect through 2025, when energy efficiency measures from the most recent three-year plans (2013-2015) run out after their ten year useful life expires.

To compare these benefits and costs properly, we discounted all dollar flows into net present values as of 2013. We calculated the net present value by applying an appropriate discount rate to dollar flows in different years, and then subtracting the sum total of discounted costs from the sum total of discounted benefits.

The discount rate is the tool that accounts for the time value of money – the concept that a dollar today is typically worth more than the same amount of money in the future because of the opportunity cost of money. A dollar today could be put into an investment or an interest-bearing activity that will typically cause it to grow in value, so that dollar today is worth more to its holder than a dollar received in the future. Further, inflation diminishes the purchasing power of dollars over time. Uncertainty about future economic outcomes, combined with a preference for nearer-term gratification, typically causes a dollar in hand today to be worth more than one tomorrow. The higher the discount rate, the lower is the present value of future cash flows.

Our analysis required choosing an appropriate discount rate. Our analysis reflects dollars in the hands of producers, who are largely private enterprises, and consumers, made up of households, businesses, government energy users, and others. Other activities add value to the macro economy of Massachusetts throughout many varied industries and areas. The choice of an appropriate discount rate needs to properly reflect the opportunity costs of these various private and public entities in society.

There is a deep literature on the proper discount rate to use in analyzing certain public policies or activities involving society rather than particular producers or consumers.

- **A private discount rate** is used when analyzing the investment options of private enterprises. The appropriate private discount rate varies, depending upon whether the economic analysis focuses on a single company (where that company's weighted average cost of capital would be appropriate) versus a group of companies (where the appropriate discount rate would reflect their collective opportunity costs).

- **A different discount rate** may be appropriate for use by government agencies when they analyze investments, when consumers look at their economic options, or when evaluating the rate at which society as a whole is willing to trade off present for future benefits.

    - **Government discount rate**: For example, in 1992, the federal government's Office of Management and Budget issued OMB Circular No. A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs." This document established guidance for discount rates used in benefit-cost and other types of economic analysis by federal agencies, with updates on certain discount rates to use when the interest rate and inflation assumptions in the budget are changed. Because "public investments and regulations displace both private investment and consumption," OMB's recommended discount rate for public investments was a real discount rate of 7 percent, which "approximates the marginal pretax rate of return on an average investment in the private sector in recent years."[53] Various analyses that involve "internal government investments" with effects on increased government revenues or decreased government costs (like "an investment in an energy-efficient building system that reduces Federal operating costs") should use a discount rate reflecting a Treasury bond with a comparable maturity to the investment. But where a government activity provides "a mix of both Federal cost savings and external social benefits," where possible the "Federal cost savings and their associated investment costs may be discounted at the Treasury rate, while the external social benefits and their associated investment costs should be discounted at the 7 percent real rate." At the time the circular was written in 1992, a 10-year Treasury was 7 percent nominal and 3.6 percent real; as of the end of 2013, these Treasury rates were 3 percent nominal and 1 percent real.[54]

- **Consumption discount rate:** Real-world conditions create differences between opportunity costs of consumers relative to private actors and governments: "Among other things, private sector returns are taxed (often at multiple levels), capital markets are not perfect, and capital investments often involve risks reflected in market interest rates. These factors drive a wedge between the *social rate* at which consumption can be traded through time (the pre-tax rate of return to private investments) and the rate at which *individuals* can trade consumption over time (the post-tax consumption rate of interest). …[For example:] …Suppose the market rate of interest, net of inflation, is 5%, and that taxes on capital income amount to 40 percent of the net return. In this case, private investments will yield 5%, of which 2% is paid in taxes to the government, with individuals receiving the remaining 3%. From a social perspective, consumption can be traded from the present to the future at a rate of 5%. But individuals effectively trade consumption through time at a rate of 3% because they owe taxes on investment earnings. As a result, the consumption rate of interest is 3%, which is substantially less than the 5% social rate of return on private sector investments (also known as the social opportunity cost of private capital)."[55]

- **Social discount rate**: "Social discounting… is discounting from the broad society-as-a-whole point of view that is embodied in benefit-cost analysis. *Private discounting*, on the other hand, is discounting from the specific, limited perspective of private individuals or

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[53] OMB Circular No. A-94 (1992), "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs." http://www.whitehouse.gov/omb/circulars_a094/

[54] OMB Budget Assumptions – Nominal and Real Treasury Interest Rates for Different Maturities (from the annual budget assumptions for the first year of the budget forecast) December 26, 2013. http://www.whitehouse.gov/sites/default/files/omb/assets/a94/dischist.pdf

[55] US Environmental Protection Agency (National Center for Environmental Economics, Office of Policy), "Guidelines for Preparing Economic Analyses," EPA 240-R-10-001, December 2010 ("EPA Guidelines"), pages 6-7 to 6-8.

firms."[56] "Implementing this distinction in practice can be complex… using a given private discount rate instead of a social discount rate may bias results as part of a benefit-cost analysis."[57]

Recent guidance provided by the U.S. Environmental Protection Agency makes the following recommendations for discount rates to use in analyzing programs that involve flows to various entities in society over different periods of time, especially when "there is a significant difference in the timing of costs and benefits, such as with policies that require large initial outlays or that have long delays before benefits are realized."[58]

> Calculate the NPV using the consumption rate of interest. This is appropriate for situations where all costs and benefits occur as changes in consumption flows rather than changes in capital stocks, i.e., capital displacement effects are negligible. As of the date of this publication, current estimates of the consumption rate of interest, based on recent returns to Government-backed securities, are close to 3%. Also calculate the NPV using the rate of return to private capital. This is appropriate for situations where all costs and benefits occur as changes in capital stocks rather than consumption flows. The Office of Management and Budget estimates a rate of 7% for the opportunity cost of private capital.[59]

For these various reasons, we used both a 3 percent ("public" or "social") discount rate, as well as a 7 percent ("private") discount rate in our analysis.

[56] EPA Guidelines, page 6-1.

[57] EPA Guidelines, page 6-1.

[58] EPA Guidelines, page 6-5.

[59] EPA Guidelines, page 6-23.