COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC UTILITIES

Joint Petition of the Department of Environmental Protection and the Department of Energy Resources Requesting the Department of Public Utilities To Adopt the Avoided Costs of Complying with The Global Warming Solutions Act, using the Marginal Abatement Cost Curve Method, In assessing the Cost Effectiveness of Energy Efficiency Programs	)	**D.P.U. 14-86**

Corrected Amended Direct Testimony of Elizabeth A. Stanton

On Behalf of the Department of Energy Resources and the Department of Environmental Protection

Regarding the Cost of Compliance with the Global Warming Solutions Act

December 4, 2014

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1. INTRODUCTION AND QUALIFICATIONS

Q. Please state your name, title, and employer.

A. My name is Elizabeth A. Stanton, and I am a Senior Economist with Synapse Energy Economics (Synapse) at 485 Massachusetts Avenue, Suite 2, Cambridge, Massachusetts 02139.

Q. Please describe Synapse Energy Economics.

A. Synapse Energy Economics is a research and consulting firm specializing in electricity and natural gas industry regulation, planning, and analysis. Our work covers a range of issues, including integrated resource planning; economic and technical assessments of energy resources; electricity market modeling and assessment; energy efficiency policies and programs; renewable resource technologies and policies; and climate change strategies. Synapse works for a wide range of clients, including attorneys general, offices of consumer advocates, public utility commissions, environmental advocates, the U.S. Environmental Protection Agency, U.S. Department of Energy, U.S. Department of Justice, the Federal Trade Commission and the National Association of Regulatory Utility Commissioners. Synapse has over 25 professional staff with extensive experience in the electricity industry.

Q. Please summarize your professional and educational experience.

A. I have more than 14 years of professional experience as an environmental economist. At Synapse, I have led studies examining environmental regulation, cost-benefit analyses, and the economics of energy efficiency and renewable energy. I have submitted expert testimony in Illinois, Vermont, New Hampshire and several federal dockets; and have authored more than 70 reports, policy studies, white papers, journal articles, and book chapters on topics related to energy, the economy, and the environment.

On behalf of the Massachusetts Clean Energy Center and its partners—the Massachusetts Departments of Energy Resources, Environmental Protection, and Public Utilities—I recently provided consulting services to estimate costs and greenhouse gas emission reductions associated with Global Warming Solutions Act (GWSA) compliance. My work analyzing climate policy in Massachusetts also includes modeling of the GWSA for Synapse's *Avoided Energy Supply Costs in New England: 2013 Report*. I describe my role in this project in Section 4 of this testimony, "GWSA Compliance and the AESC 2013 Study."

Prior to joining Synapse, I was a Senior Economist with the Stockholm Environment Institute's (SEI's) Climate Economics Group, where I was responsible for leading the organization's work on the Consumption-Based Emissions Inventory (CBEI) model and on water issues and climate change in the western U.S. While at SEI, I led domestic and international studies commissioned by the United Nations Development Programme, Friends of the Earth-U.K., and Environmental Defense.

My articles have been published in *Ecological Economics*, *Renewable Resources Journal*, *Environmental Science & Technology*, and other journals. I have also published books, including *Climate Economics: The State of the Art* (Routledge, 2013), which I co-wrote with my colleague at Synapse, Dr. Frank Ackerman. I am also coauthor of *Environment for the People* (Political Economy Research Institute, 2005, with James K. Boyce) and coeditor of *Reclaiming Nature: Worldwide Strategies for Building Natural Assets* (Anthem Press, 2007, with Boyce and Sunita Narain).

I earned my Ph.D. in economics at the University of Massachusetts-Amherst, and have taught economics at Tufts University, the University of Massachusetts-Amherst, and the College of New Rochelle, among others. My curriculum vitae is attached as Exhibit EAS-1.

Q. On whose behalf are you testifying in this case?

A. I am testifying on behalf of the Massachusetts Department of Energy Resources and the Massachusetts Department of Environmental Protection.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is:

1) to explain the appropriate methodology for determining the cost of compliance with the GWSA St. 2008, c. 298;[1]
2) to determine the cost of GWSA compliance for 2020; and
3) to determine the cost of GWSA compliance for 2030.

My testimony is accompanied by that of Tim Woolf, Vice President of Synapse Energy Economics.

Q. How is your testimony organized?

My testimony is organized as follows:

1) Introduction and Qualifications
2) Summary of Conclusions and Recommendations
3) Methodology for Determining the Cost of GWSA Compliance
4) GWSA Compliance and the AESC 2013 Study
5) GWSA Emission Reduction Target for 2020
6) Policy-Based Emission Reductions Necessary for 2020 GWSA Compliance
7) Demonstration of Cost of 2020 GWSA Compliance Methodology
8) Policy-Based Emission Reductions Necessary for 2030 GWSA Compliance
9) Demonstration of Cost of 2030 GWSA Compliance Methodology
10) Recommended GWSA Compliance Costs

2. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Q. Please summarize your primary conclusions.

A. My testimony explains the appropriate methodology for determining the cost of GWSA compliance. This methodology is called the "marginal abatement cost curve," and consists of adding the expected greenhouse gas emission reductions from policies—starting with the least expensive policy (on a per metric ton basis) and moving toward the

[1] The GWSA includes the Climate Protection and Green Economy Act codified at M.G.L. c. 21N.

most expensive—until the total emissions reduction achieved by the policies is sufficient for GWSA compliance.

I determine the cost of GWSA compliance for 2020 to be $52 per metric ton of carbon dioxide equivalent (CO_2e)[2], $20 per MWh, $0.28 per therm, and $3.8 per MMBtu.[3] This is the cost of Clean Energy Imports—the "marginal" policy (i.e., the most expensive policy necessary) to achieve a 25-percent reduction in statewide greenhouse gas emissions from 1990 levels for 2020. Clean Energy Imports are the import of hydroelectric generation from Canada using new and existing transmission lines. The incremental cost of this policy (above conventional generation) reflects the levelized cost of the new transmission needed to bring these Canadian resources to New England load centers.

I determine the cost of GWSA compliance for 2030 to be $59 per metric ton of CO_2e, $23 per MWh, $0.31 per therm, and $4.3 per MMBtu. This is, again, the cost of Clean Energy Imports, which is the marginal policy to achieve a 43-percent reduction in statewide greenhouse gas emissions from 1990 levels for 2030.

Q. Please summarize your primary recommendations.

A. I offer the following recommendations: The cost of compliance with GWSA can be calculated for 2020 and 2030. In his testimony, my colleague Mr. Woolf explains that compliance with GWSA is required by Massachusetts law and that although the costs cannot be quantified with absolute certainty it is still appropriate to take these costs into account when calculating the GWSA compliance costs avoided by energy efficiency measures. I recommend that the cost of GWSA compliance be included in future assessments of the costs avoided by energy efficiency programs and measures.

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[2] Not all greenhouse gases have the same heat-trapping capacity. To account for these differences, a standard relating the heat trapping potential of each greenhouse gas to an equivalent quantity of carbon dioxide, over a given time horizon, has been developed. Emissions shown in this document utilize this standard, and are expressed in units of metric tons of carbon dioxide equivalent (CO_2e).

[3] All monetary values in this testimony are reported in 2013 dollars.

3. <u>METHODOLOGY FOR DETERMINING THE COST OF GWSA COMPLIANCE</u>

Q. Can the costs of complying with GWSA in 2020 and 2030 be determined?

A. Yes.

Q. Have you identified an appropriate methodology for determining the cost of GWSA compliance?

A. Yes.

Q. What key components are necessary to determining the cost of GWSA compliance?

A. Determination of the cost of GWSA compliance requires the following components:

1) ***Total amount of emission reductions required:*** The required policy-based emission reductions necessary for GWSA compliance in a given year;
2) ***Policy options:*** The policy options capable of reducing greenhouse gas emissions in a given year;
3) ***Cost (per metric ton of CO_2e) for each policy option:*** The expected cost per metric ton of CO_2e emission reduction for each potential policy considered in a given year; and
4) ***Emission reductions associated with each policy option:*** The expected CO_2e emission reduction for each potential policy considered in a given year.

Q. Using these components, how is the cost of GWSA compliance determined?

A. The cost of GWSA compliance for a given year is determined using the following three steps.

Step A: Policy options are placed in order of their cost per metric ton of CO_2e reduction for a given year, from least expensive to most expensive.

Step B: Moving from the least expensive to the most expensive, policies are added one at a time until the point is reached where the total emission reductions associated with the policies are sufficient to comply with GWSA requirements. The last policy added on is considered to be the "marginal policy."

Step C: The cost per metric ton of the identified marginal policy is the cost of GWSA compliance for the given year.

This method is commonly referred to as a marginal abatement cost curve.

Q. Has this method been used previously to investigate the cost of GWSA compliance?

A. Yes. The marginal abatement cost curve method described above was used to investigate the cost of GWSA compliance in the *Avoided Energy Supply Costs in New England: 2013 Report*, which I discuss in the next section of my testimony.

Q. What are the critical drivers of the cost of GWSA compliance?

A. The cost of GWSA compliance is the cost of the marginal resource and is, therefore, driven by three main components:

(1) the total amount of emission reductions required (i.e., the "reduction target");

(2) the emission reductions associated with each policy option; and

(3) the cost (per metric ton of CO_2e) for each policy option near the margin.

The cost (per metric ton of CO_2e) for policies located at the low end of the marginal abatement cost curve for GWSA compliance (e.g., energy efficiency and other policies with net benefits or "negative costs") could vary significantly and still have no impact on the marginal abatement cost.

In contrast, the "width" of each policy (i.e., each policy's anticipated emission reductions)—even if the policy provides net benefits—is critical to determining the cost of GWSA compliance. Variations in these values could shift the margin to another policy. Similarly, changes in the emission reduction target could shift the margin to another policy, resulting in a different marginal abatement cost for GWSA compliance.

4. <u>GWSA COMPLIANCE AND THE AESC 2013 STUDY</u>

Q. What is the 2013 New England Avoided Energy Supply Cost Study?

A. The regularly conducted New England Avoided Energy Supply Cost (AESC) study projects marginal energy supply costs that would be avoided due to reductions in electricity, natural gas, and other fuels resulting from energy efficiency programs offered to customers throughout New England. This report is developed with participation from more than 25 stakeholder groups and study sponsors, including energy efficiency Program Administrators, utilities, regulators, and consumer and environmental advocates. The latest version—*Avoided Energy Supply Costs in New England: 2013 Report* (AESC 2013)—was published in July 2013 (attached as Exhibit EAS-2).

Q. What was your role in the AESC 2013 study?

A. I was the lead analyst and author of Chapter 4 of AESC 2013, which examines the avoided environmental costs of both existing environmental regulations (called embedded costs in AESC) and environmental externalities (called "non-embedded" costs in AESC). This chapter explicitly evaluated the avoided cost associated with the Massachusetts electric sector's compliance with the GWSA.

Q. Did AESC 2013 determine whether compliance with GWSA would impact directly on generators?

A. Yes. AESC 2013 determined that GWSA compliance would have an impact on generators and established a method for determining the cost of compliance with GWSA.

Q. Did AESC 2013 determine whether compliance with GWSA would impact natural gas and oil use in buildings?

A. No, but that analysis has been conducted for this testimony as explained below.

Q. What was the method for determining the cost of compliance with GWSA established in AESC 2013?

A. AESC 2013 established a "marginal abatement cost curve" method for determining the cost of compliance with GWSA. In this widely used approach, an economic supply curve of policies expected to contribute to accomplishing emission reduction goals is constructed. Such a supply curve is composed of information regarding the cost per ton of greenhouse gas emission reduction for each policy and the expected emission reductions possible from each policy; these policies are ordered from least to most expensive. The marginal cost of compliance is the per-ton cost of the most expensive policy required to achieve the GWSA emissions limit for a given year.

AESC 2013 summarizes its analysis of the cost of compliance with GWSA as follows (p.1-12):

> - The Massachusetts Clean Energy [and] Climate Plan (CECP) assumes the electricity sector will achieve significant reductions in emissions by 2020 under its Business as Usual Forecast. The CECP then identifies six policy measures the electricity sector could use to comply with GWSA targets in 2020 and beyond, as well as the quantity of reductions and cost per ton of reduction from each. The AESC 2013 Base Case reflects the compliance measures that are currently enforced for the Massachusetts electricity sector except for energy efficiency, which are RPS [Renewable Portfolio Standard], RGGI [Regional Greenhouse Gas Initiative], and EPA Power Plant Rules. The remaining compliance measures are all cost-effective energy efficiency, the Clean Energy Import Strategy (CEI) and a Clean Energy Performance Standard (CEPS).
>
> - The Massachusetts electricity sector will require reductions from a CEPS or other additional component in order to comply with the GWSA at some point from 2020 onward. However, there are unresolved policy questions regarding the CECP targets for the electricity sector beyond 2020 and the inventory method for accounting for reductions in that sector. As a result, the project team could not determine the size of reductions that would be required in the electricity sector each year and therefore could not quantify and credibly support an estimate of the cost of the marginal resource required to achieve those reductions.

Q. Did AESC 2013 provide a high-level estimate of the cost of GWSA compliance in 2020?

A. Yes. AESC 2013 did provide a high-level estimate of the cost of compliance in 2020 as follows (pp.1-12 to 1-13):

- In the absence of detailed modeling, the project team identified additional renewable generation, incremental to RPS quantities, as the marginal resource for electric-sector compliance with the GWSA. If the quantity of additional renewable generation required for GWSA compliance in a given year is comparable to the AESC 2013 projected quantity of renewable generation added to meet RPS requirements in that year, it is reasonable to expect the cost of that additional renewable generation in that year to be comparable to the REC prices estimated for Massachusetts for that year (e.g., $18.40/MWh in 2020, per Exhibit 6-30) plus the AESC 2013 estimate of electric energy costs for Massachusetts in that year. If the quantity of additional renewables required for GWSA compliance is significantly larger than those added to meet RPS requirements, the cost of the marginal resource required to achieve those larger reductions would have to be determined through new modeling.

AESC 2013 presumed additional GWSA compliance measures—beyond those with clear costs and emission reductions in the CECP—would be accomplished by providing incentives for developing renewables classified as Class I under the Massachusetts RPS, and would therefore need the same Renewable Energy Certificate (REC) incentive as Class I renewables. AESC 2013 is careful to point out that its estimate is valid only for a "limited quantity" of additional renewables comparable to projected RPS requirements. (Note that, subsequent to publication of AESC 2013, it became clear that acquiring even that limited quantity of additional renewables would likely require major investments in new transmission lines and the cost of that incremental transmission was not reflected in the high-level estimate of the cost of compliance in 2020.[4])

AESC 2013 also points out that if the quantity of additional renewables ultimately required to comply with the GWSA in 2020 or later years, would be materially larger than the quantity AESC 2013 projected to meet Massachusetts RPS requirements, those quantities of incremental renewables would likely come at a price different from the Class I REC (pp.4-59 to 4-60):

[4] Personal communication between Rick Hornby, Synapse Energy Economics, and Jason Gifford, Sustainable Energy Advantage. October 23, 2013.

> In contrast, it is possible that the quantity of additional renewables the Massachusetts electricity sector will require for GWSA compliance in 2020 or beyond will be significantly larger than the quantity added to meet RPS requirements in the AESC 2013 Base Case. For example, an updated BAU [business-as-usual] forecast may indicate that the Massachusetts electricity sector is not on track to emit 4.4 million short tons less CO_2 in 2020 than in 1990. Similarly, updated estimates may project a smaller emission reduction from current energy efficiency programs than the CECP had anticipated. Such analyses may indicate that the Massachusetts electricity sector will require reductions much greater than the renewable generation additions for RPS compliance modeled in AESC 2013. If so, the cost of the marginal resource required to achieve those larger reductions would have to be determined through new modeling. The addition of such a significant quantity of renewable generation could have a material impact on the marginal cost of energy in the New England market, and hence could affect the AESC 2013 estimates of avoided wholesale energy costs for each state. For this reason, the impact of a significant additional quantity of renewable energy should be estimated through additional modeling that is not within the scope of the current analysis.

Q. Did AESC 2013 model GWSA compliance throughout its planning horizon?

A. No. The AESC project team concluded that, as of July 2013, several unresolved policy issues made it impractical to model the cost of GWSA compliance through the 2043 (30-year) planning horizon. The three policy issues for which details were not available to the project team at the time were the Massachusetts Greenhouse Gas Emissions Inventory method, the costs and savings of the Clean Energy Performance Standard, and the GWSA emission reduction target for the Electric Supply sector in 2030.

Q. Have the unresolved policy issues discussed in AESC 2013—cited as challenges to modeling the cost of GWSA compliance—been resolved?

A. Since publication of AESC 2013, two of the key challenges to more refined modeling of the cost of GWSA compliance in 2020 and beyond have been resolved, and the third challenge can be accommodated.

Massachusetts Greenhouse Gas Emissions Inventory Method: As of July 2013, Massachusetts' emissions inventory method did not have the capability to account for emission reductions from Massachusetts utilities' purchase of out-of-state RECs for RPS compliance, or from any special claim the Commonwealth might have on purchases of Canadian hydro-electric generation. However, in April 2014, MassDEP posted its *2008-2010 Massachusetts' Greenhouse Gas Emissions Inventory,* which includes a revision to the electric-sector inventory method to account for Massachusetts utilities' purchase of out-of-state RECs and out-of-state purchase of Massachusetts RECs (attached as Exhibit EAS-3). This framework lays the foundation for adjustment of Massachusetts electric-sector emissions for special claims on hydro-electric purchases, should such claims exist in the future.

Clean Energy Performance Standard: AESC 2013 determined that electric-sector GWSA compliance in 2020 and beyond would likely require new policy measures in addition to the specific measures with clear costs and emission reductions identified in the CECP. A major new policy measure that the CECP introduces (but for which it does not describe clear costs and emission reductions) is the Clean Energy Performance Standard (CEPS).[5] However, in October 2013 Synapse completed a study for the Massachusetts Departments of Energy Resources, Environmental Protection and Public Utilities—supported by the Massachusetts Clean Energy Center—that investigated a Clean Energy Standard. This report, *A Clean Energy Standard for Massachusetts, Final Report*, is submitted in this docket as Exhibit EAS-4. It describes the expected costs and emission reductions associated with the CEPS policy in detail.

2030 Emission Reduction Target: On December 28, 2010, the Secretary of Energy and Environmental Affairs established a specific emissions limit for 2020 (attached as Exhibit EAS-5). To date, no 2030 emissions limit has been established. AESC 2013 cited the absence of a specific GWSA emission reduction target for the electric sector in 2030 as an obstacle for modeling the cost of GWSA compliance.[6] In my opinion, the lack of a 2030 emissions limit should not prevent the Massachusetts' Department of Public Utilities from establishing first-order estimates of the cost of GWSA compliance in years

[5] *Massachusetts Clean Energy and Climate Plan for 2020* (CECP), Exhibit EAS-6, p.47-48
[6] AESC 2013, Exhibit EAS-2, p.4-52

after 2020, as demonstrated in this testimony. Further, the framework recommended in this testimony can and should be periodically updated as additional or updated information becomes available.

5. <u>GWSA EMISSION REDUCTION TARGET FOR 2020</u>

Q. Since the publication of AESC 2013, have you made an assessment of the cost of 2020 GWSA compliance?

A. Yes.

Q. How did you determine the cost of GWSA compliance in 2020?

A. To determine the cost of GWSA compliance in 2020 I assembled the following four components and then followed the three steps outlined below:

Components in cost of GWSA compliance analysis:

1. ***Total amount of emission reductions required:*** The required policy-based emission reductions necessary for GWSA compliance in a given year. (See Sections 5 and 6 of this testimony: "GWSA Emission Reduction Target for 2020" and "Policy-Based Emission Reductions Necessary for 2020 GWSA Compliance.")
2. ***Policy options:*** The policy options capable of reducing greenhouse gas emissions in a given year. (See Section 7 of this testimony: "Demonstration of Cost of 2020 GWSA Compliance Methodology.")
3. ***Cost (per metric ton of CO_2e) for each policy option:*** The expected cost per metric ton of CO_2e emission reduction for each potential policy considered in a given year. (See Section 7 of this testimony: "Demonstration of Cost of 2020 GWSA Compliance Methodology
4. ***Emission reductions associated with each policy option:*** The expected CO_2e emission reduction for each potential policy considered in a given year. (See Section 7 of this testimony: "Demonstration of Cost of 2020 GWSA Compliance Methodology.")

Steps taken to determine the cost of GWSA compliance :

Step A: Policy options are placed in order of their cost per metric ton of CO_2e reduction for a given year, from least expensive to most expensive. (See Section 7 of this testimony: "Demonstration of Cost of 2020 GWSA Compliance Methodology.")

Step B: Moving from the least expensive to the most expensive, policies are added one at a time until the point is reached where the total emission reductions associated with the policies are sufficient to comply with GWSA requirements. The last policy added on is considered to be the "marginal policy." (See Section 7 of this testimony: "Demonstration of Cost of 2020 GWSA Compliance Methodology.")

Step C: The cost per metric ton of the identified marginal policy is the cost of GWSA compliance for the given year. (See Section 7 of this testimony: "Demonstration of Cost of 2020 GWSA Compliance Methodology.")

Q. Did you determine the amount of emission reductions required in 2020 for GWSA compliance?

A. Yes.

Q. What greenhouse gas emission reduction does the GWSA require for 2020?

A. GWSA requires that:

- Statewide greenhouse gas emissions be reduced to between 10 and 25 percent below 1990 statewide greenhouse gas emissions in 2020; and
- A 2020 emissions limit, and a plan for achieving this limit, be established by January 1, 2011.

Q. Has a 2020 greenhouse gas emission reduction target been set and a plan for achieving that target released?

A. Yes. On December 28, 2010, the Secretary for Energy and Environmental Affairs (EEA) established a legally binding statewide greenhouse gas emission limit for 2020 of 25 percent below the statewide 1990 greenhouse gas emissions level (attached as Exhibit EAS-5). On December 29, 2010, EEA published the *Massachusetts Clean Energy and*

Climate Plan for 2020 (CECP), which describes a portfolio of policies aimed at enabling the Commonwealth to comply with its 2020 statewide greenhouse gas emissions limit of 25 percent below 1990 statewide greenhouse gas emissions (attached as Exhibit EAS-6).

Q. To what maximum statewide greenhouse gas emission level does Massachusetts need to limit itself in 2020?

A. Compliance with GWSA in 2020 requires that Massachusetts 1990 statewide greenhouse gas emission levels be reduced by 25 percent, from 94.4 million metric tons of CO_2e to 70.8 million metric tons. This is a 25-percent, or 23.6 million metric ton, reduction below 1990 levels (see background material to the CECP attached as Exhibit EAS-7).

Q. Does the CECP describe emission reduction policies equal to a 25-percent, or 23.6 million metric ton, reduction below 1990 levels?

A. No. The CECP provides a mid-range estimate that its strategies would attain reductions of 25.6 million metric tons of CO2e and estimates "business-as-usual" emission reductions (discussed below) of 0.2 million metric tons. Together these reductions total 25.8 million metric tons, or 27.3 percent of 1990 levels, slightly more than the amount of reductions required for GWSA compliance.

Q. In the CECP, do all economic sectors reduce greenhouse gas emissions by 25 percent?

A. No. The CECP sets different target reductions for different economic sectors. Background materials to the CECP break down its 27.3 percent (25.8 million metric ton CO_2e) estimated total reduction for 2020 into four sectors: Buildings, Electric Supply, Transportation, and Non-Energy (attached as Exhibit EAS-7). Each sector has a 2020 emission reduction target (which includes both policy-based and business-as-usual changes to emissions) and, therefore, an amount of estimated emissions consistent with GWSA compliance in 2020 as shown in Table 1 (calculations used to produce Table 1 are attached as Exhibit EAS-8 and include emission reduction assumption taken from Exhibit EAS-9 and Exhibit EAS-10). Buildings and Electric Supply sectors are combined in Table 1, because the CECP includes several policies that affect both sectors jointly.

Table 1. Massachusetts 1990 emissions, CECP 2020 Total Reduction Target, and 2020 GWSA-Compliant Emissions per the CECP

(million metric tons CO_2-e) Sector	1990 Emissions	less	CECP 2020 Reduction Target	equals	2020 GWSA-Compliant Emissions per CECP
Statewide Total	**94.4**		**25.8**		**68.6**
Buildings and Electric Supply	57.4		28.8		28.6
Transportation	30.4		-0.4		30.9
Non-Energy	6.6		-2.6		9.1

CECP emission levels for GWSA compliance in 2020 in the Transportation and Non-Energy sectors are larger than these sectors' 1990 emissions, meaning that the CECP goals for these two sectors are caps on emission <u>increases</u> in 2020 (shown as negative reductions in Table 1) rather than required emission reductions. To be clear, in the CECP, the progress achieved in the Transportation and Non-Energy sectors for 2020 is that growth in emissions in these sectors is limited to just 1-percent and 39-percent, respectively, above their 1990 levels. In the absence of CECP policies, these two sectors would (according to the CECP) be expected to instead increase their emissions by 25-percent and 68-percent above their 1990 levels.

Q. In the CECP, is this 27.3-percent, 25.8 million metric tons, CO_2e emission reduction target achieved entirely by new policy measures?

A. No. The CECP plans for a 27.3-percent emission reduction below 1990 emission levels using a combination of:

(1) new policy measures expected to come into effect after the GWSA was established (25.6 million metric tons); and

(2) a "business-as-usual" estimate of emissions in 2020 in the absence of new policy measures (0.2 million metric tons).

Q. What determines a business-as-usual emission projection?

A. The Climate Protection and Green Economy Act, M.G.L. c. 21N § 3(a), required MassDEP to "reasonably project what the emissions level will be in calendar year 2020 if no measures are imposed to lower emissions other than those formally adopted and implemented as of January 1, 2009. This projection shall hereafter be referred to as the projected 2020 business as usual level." In the absence of new policy measures aimed at lowering emissions, 2020 "business-as-usual" greenhouse gas emissions would be determined by Massachusetts policy measures in effect at the time that the GWSA was enacted, policy measures taken by federal agencies, and non-policy effects such as changes in fuel prices, changes in economic conditions, and other factors not directly driven by policy.

GWSA compliance requires the Commonwealth to implement policies aimed at ensuring that in 2020 statewide greenhouse gas emissions are less than or equal to 70.8 million metric tons CO_2e. The difference between projected 2020 business-as-usual greenhouse gas emissions and the GWSA-compliant 2020 greenhouse gas emissions level is the amount of new policy-based emission reductions required to achieve compliance. Together (1) the difference between 1990 greenhouse gas emissions and expected 2020 business-as-usual greenhouse gas emissions, and (2) the expected new policy-based greenhouse gas emission reductions must sum to at least the total 25-percent (23.6 million metric tons CO_2e) emission reduction required for GWSA compliance (see Exhibit EAS-7 and Exhibit EAS-8).

Q. Does the CECP include assumptions regarding business-as-usual emissions for 2020?

A. Yes. The CECP includes a 2020 statewide business-as-usual projection of 94.2 million metric tons of CO_2e (as compared to 94.4 million metric tons in 1990). By sector, the CECP projects 2020 business-as-usual emissions of: Buildings, 21.3 million metric tons; Electric Supply, 23.8 million metric tons; Transportation, 38.1 million metrics tons; and Non-Energy, 11.0 million metric tons (see Exhibit EAS-7 and Exhibit EAS-8).

Q. For this analysis, did you need to update the CECP's business-as-usual projections for future years?

A. Yes. While business-as-usual projections are not affected by new policy choices, they are certainly affected by economic factors such as changing fuel prices and the pace of economic growth. For purposes of this analysis, the business-as-usual emission projection made for the CECP has been updated to reflect the best information currently available regarding past, current, and future economic conditions.

Q. Is the business-as-usual emission projection used in this analysis the same as the business-as-usual emission projection used in the CECP?

A. No. The updated business-as-usual projection used in this analysis differs from the CECP business-as-usual projection, as discussed below.

6. POLICY-BASED EMISSION REDUCTIONS NECESSARY FOR 2020 GWSA COMPLIANCE

Q. Have you made an assessment of the policy-based emission reductions necessary for 2020 GWSA compliance?

A. Yes.

Q. In your assessment, what do you assume regarding emission reductions necessary in the Transportation and Non-Energy sectors?

A. I assume that the Transportation and Non-Energy sectors will achieve the 2020 sectoral emissions levels set out in the CECP (attached as Exhibit EAS-6 and Exhibit EAS-7): Transportation, 38.1 million metric tons; and Non-Energy, 11.0 million metric tons. In 2020, emission reductions in the Transportation and Non-Energy sectors will still be—as they are today—largely unrelated to emission reductions in the Buildings and Electric Supply sectors, and therefore largely unrelated to energy efficiency measures taken in these sectors. My testimony focuses on the emission reductions in the closely interrelated Buildings and Electric Supply sectors that are likely to be interconnected with statewide building energy efficiency policies. The avoided cost methodology is a durable approach, but it is recommended in this testimony that the business-as-usual emissions forecast and policy-specific avoided costs used in future years be periodically updated as additional or updated information becomes available, including any update to expected sectoral emission reductions.

Q. Have you made updated projections of 2020 business-as-usual greenhouse gas emissions in the Buildings and Electric Supply sectors?

A. Yes. My analysis completed for this testimony includes updated business-as-usual 2020 greenhouse gas emissions forecasts for the Buildings and Electric Supply sectors.

Q. How did you project updated 2020 business-as-usual emissions in the Electric Supply sector?

A. For the Electric Supply sector, I multiply a projected 2020 business-as-usual emissions rate for New England generation (including imports) by projected 2020 business-as-usual retail electric sales for Massachusetts.

The business-as-usual emissions rate was calculated using the 2020 generation and imports resource mix for New England used in AESC 2013, which includes expected fuel price changes, retirements and additions, and an expected load with no new efficiency measures after 2013. I adjust the 2020 resource mix to remove all renewable resources constructed after the Massachusetts RPS came into effect in 2008, and replace renewables with natural gas generation—assumed to be the marginal resource in New England—to maintain the same generation level. I use the AESC 2013 emission rates by resource, but estimate a New England average emission rate that is higher than that of AESC 2013 due to additional generation from natural gas.

Massachusetts' 2020 business-as-usual load was assumed to be the same load forecast used for AESC 2013: the ISO-NE 2012 Capacity, Energy, Load and Transmission (CELT) Base forecast (attached as Exhibit EAS-11) that excludes new energy efficiency[7]

[7] For the 2012 CELT forecast, Synapse used the annual load values, unadjusted for energy efficiency, developed by ISO-NE for 10-year planning and reliability studies. The load forecast is derived from a statistical model that is based on historic, annual data to project total energy consumption within the ISO-NE area. The objective of the model is to incorporate "underlining relationships among input variables to predict electric consumption as

(since energy efficiency impacts are policy-based), adjusted to remove the load reductions associated with increasingly stringent Federal Appliance standards (see Exhibit EAS-11 tab 9 and Exhibit EAS-13) and escalated slightly to account for behind-the-meter solar generation constructed after 2008 (which is replaced with natural gas generation).

Based on these assumptions, I project that updated 2020 business-as-usual emissions in the Electric Supply sector will be 23.6 million metric tons of CO_2e (as compared to 23.8 million metric tons projected in the CECP) (calculations attached as Exhibit EAS-8).

Q. Are there any critical differences in the assumptions regarding the updated 2020 business-as-usual emissions used in your analysis as compared to those used in the CECP?

A. Yes. The CECP includes a policy measure called "More Stringent EPA Power Plant Rules" that represents the impact of federal environmental regulations on the retirement of coal-fired power plants (attached as Exhibit EAS-6, p.44). Under this policy, the CECP estimates 1.2 million metric tons of policy-based emission reductions associated with the retirement of the Somerset and Salem Harbor power plants. The AESC modeling that underlies my business-as-usual emission projection for the Electric Supply sector includes the retirement of numerous coal- and oil-fired power plants by 2020, including Somerset and Salem (attached as Exhibit EAS-2, p.5-10), since I am appropriately using the most up-to-date information available on the power plants that can supply electricity to the New England electric grid.

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accurately as possible" (A General Discussion of the Forecast Model Structures of the ISO New England Long Run Energy and Seasonal Peak Forecasts for the 2012 CELT Report and 2012 Regional System Plan. p. 1, http://www.iso-ne.com/trans/celt/fsct_detail/2012/forecastdiscussion2012.pdf). Because the model is based on historical relationships, increasing penetration of energy efficiency programs are largely omitted from the 2012 CELT forecast (AESC 2013, p. 5-3). The structure of the model does allow for demand elasticity (rising electricity prices would put downward pressure on energy demand). In addition, the 2012 forecast includes existing demand side resources that participate in the forward capacity auction (FCA) (thereby inflating the actual loads on the system) and also includes preset estimates regarding the impact of new Federal Electric Appliance Standards.

The complementary impacts of counting Salem and Somerset retirements as contributing to business-as-usual emission reductions instead of policy-based emission reductions are: (1) lower projected updated 2020 business-as-usual emissions and, consequently, lower policy-based emission reductions needed to reach the 2020 GWSA compliance emission target; and (2) the loss of a 1.2 million metric ton policy measure (older power plant retirements) that is included in the CECP as a means to reduce 2020 emissions.

The same logic holds for the supplemental strategy of the retirement of Brayton Point mentioned in the Global Warming Solutions Act 5-Year Progress Report (attached as Exhibit EAS-12). That is, since the retirement of Brayton Point is already included in the lower projected updated 2020 business-as-usual emissions, it is not appropriate to include a Brayton Point supplemental strategy in the marginal abatement cost curve developed in this testimony.

Q. How did you project updated 2020 business-as-usual emissions in the Buildings sector?

A. For the Buildings sector, I use publicly available projections of natural gas and fuel oil use in the residential, commercial, and industrial sectors.

The CECP has projected that in the absence of new efficiency measures, 2020 consumption of natural gas in the Buildings sector will result in the emission of 12.3 million metric tons (attached as Exhibit EAS-13; see also Exhibit EAS-14). The implied 2013-2020 annual growth rate for natural gas in this forecast is 1.1 percent, which is identical to the 2013-2028 annual growth rate for Massachusetts' natural gas consumption implied in Black and Veatch's 2013 study of New England natural gas infrastructure and electric generation, which also assumes no new Buildings sector energy efficiency measures in its base case (attached as Exhibit EAS-15). As a point of comparison, the U.S. Energy Information Administration (EIA) forecasts natural gas consumption for New England, but all of its scenarios include some new Buildings sector efficiency measures. In the EIA scenario that includes the least efficiency ("2012

Demand Technology Case"), the 2013-2020 annual growth rate for New England's Buildings sector natural gas consumption is 0.8 percent (see Exhibit EAS-14).

EIA's 2020 forecast of fuel oil consumption for New England is 112 million MMBtus in its least efficient scenario. Over the past two decades, Massachusetts has been responsible for approximately 35 percent of New England's heating oil consumption. Using this same percentage, Massachusetts' share of emissions from fuel oil would be 8.2 million metric tons in 2020 (calculations attached as Exhibit EAS-14).[8]

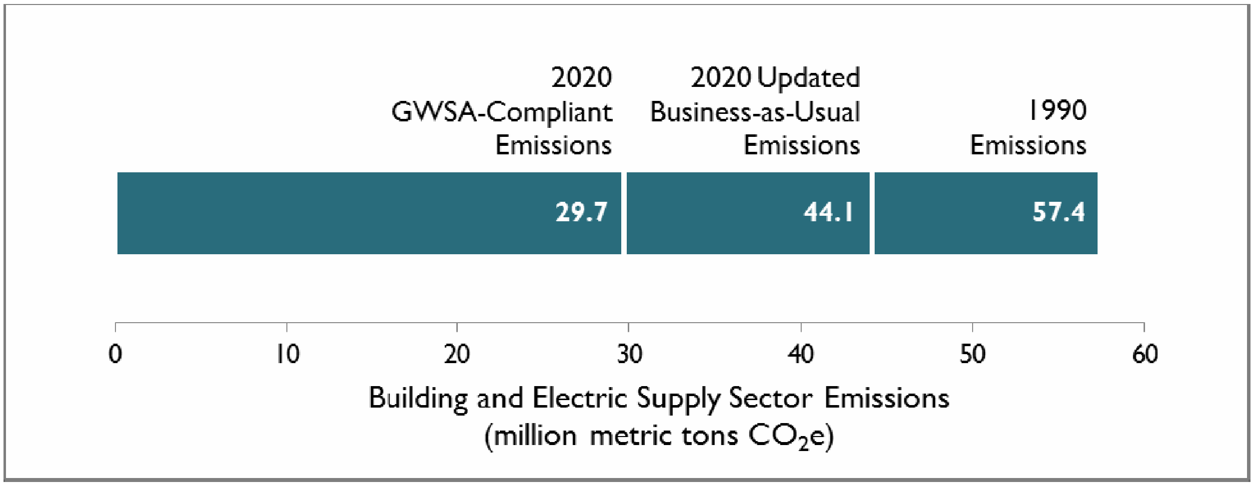
Based on these assumptions, I project that updated 2020 business-as-usual emissions in the Buildings sector will be 20.5 million metric tons of CO_2e (as compared to 21.3 million metric tons projected in the CECP) (calculations attached as Exhibit EAS-14).

Q. What is your projection of Massachusetts' 2020 business-as-usual greenhouse gas emissions in the combined Buildings and Electric Supply sectors?

A. Based on these updated 2020 business-as-usual forecasts—Buildings 20.5 million metric tons, and Electric Supply 23.6 million metric tons—I project slightly lower combined Buildings and Electric Supply 2020 business-as-usual emissions (44.1 million metric tons) than did the CECP (45.1 million metric tons) (calculations attached as Exhibit EAS-8) as shown in Figure 1.

[8] Based on the fuel oil Btu to metric ton CO_2 conversion rate used by MassDEP in Exhibit EAS-11.

Figure 1. Massachusetts Buildings and Electric Supply sector 1990 emissions, 2020 updated business-as-usual emissions, and 2020 GWSA-compliant emissions



Q. What is the difference between 1990 Buildings and Electric Supply sector emissions and your updated projections of 2020 business-as-usual greenhouse gas emissions for these sectors?

A. The difference between 1990 emissions (57.4 million metric tons CO_2e) and updated 2020 business-as-usual projected emissions in the Buildings and Electric Supply sectors (44.1 million metric tons) is 13.3 million metric tons (calculations attached as Exhibit EAS-8). This difference may also be referred to as the "business-as-usual emission reduction."

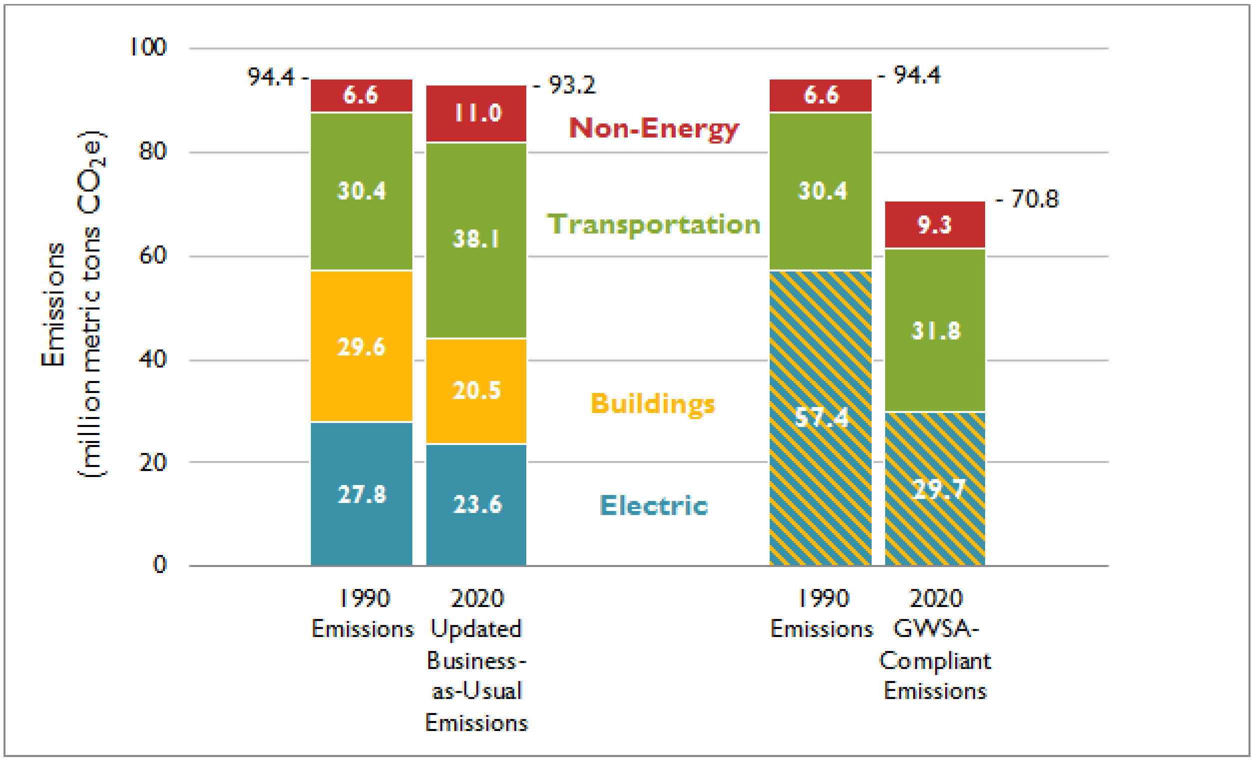
Q. What statewide 2020 business-as-usual emission reduction is implied by this updated business-as-usual projection for the Buildings and Electric Supply sectors?

A. Using this updated business-as-usual projection for the Buildings and Electric Supply sectors, statewide 2020 business-as-usual emissions are projected to be 93.2 million metric tons CO_2e: the sum of the updated business-as-usual Buildings and Electric Supply sectors projection for 2020 (44.1 million metric tons), the CECP business-as-usual Transportation sector projection (38.1 million metric tons), and the CECP business-as-usual Non-Energy sector projection (11.0 million metric tons).

The difference between 1990 statewide emissions (94.4 million metric tons) and updated statewide 2020 business-as-usual projected emissions (93.2 million metric tons) is 1.2

million metric tons (calculations attached as Exhibit EAS-8) as shown in Figure 2. Buildings and Electric Supply sector emissions for 2020 GWSA compliance are combined in Figure 2 because the CECP includes several policies that affect both sectors jointly.

Figure 2. Massachusetts 1990 emissions, 2020 updated business-as-usual emissions, and 2020 GWSA compliant emissions



Q. Do you consider the sensitivity of the calculated cost of 2020 GWSA compliance to the assumption that a 25-percent reduction in statewide greenhouse gas emissions is required, rather than the 27.3-percent reduction in greenhouse gas emissions from the Buildings and Electric Supply sectors used in the CECP?

A. Yes. I discuss the results of this sensitivity analysis below in Section 10. In brief, using a 27.3-percent reduction in place of a 25-percent reduction would have no impact on the marginal resource in 2020 or the cost of 2020 GWSA compliance.

Q. Based on your updated projection of business-as-usual greenhouse gas emissions for 2020, what policy-based emission reductions are necessary for 2020 GWSA compliance in the Buildings and Electric Supply sectors?

A. Required statewide policy-based emission reductions are the difference between the statewide 2020 GWSA emission reduction target (25-percent below 1990 levels, or 23.6 million metric tons CO_2e) and statewide business-as-usual emission reductions (1.2 million metric tons). Statewide policy-based emission reductions required for GWSA compliance in 2020 are, therefore, 22.4 million metric tons.

I allocate policy-based reductions to each of the four economic sectors in proportion to the share of policy-based emission reductions from 1990 for 2020 from each sector reported in the CECP: Buildings and Electric Supply sectors, 64 percent; Transportation sector, 28 percent; and Non-Energy sector, 7 percent (calculations attached as Exhibit EAS-8).

The required 2020 policy-based emission reduction for the Buildings and Electric Supply sectors combined is 14.4 million metric tons (calculations attached as Exhibit EAS-8). In comparison, the CECP calls for a 2020 policy-based emission reduction of 16.5 million metric tons in the Buildings and Electric Supply sectors.

7. DEMONSTRATION OF COST OF 2020 GWSA COMPLIANCE METHODOLOGY

Q. As described above, the first component in the marginal abatement cost curve methodology is the amount of emission reductions required in 2020 for GWSA compliance. What amount of Buildings and Electric Supply sector emission reductions did you determine was required in 2020 for GWSA compliance?

A. The policy-based emission reduction necessary from the Buildings and Electric Supply sectors for 2020 GWSA compliance is 14.4 million metric tons CO_2e.

Q. As described above, the other three components in the marginal abatement cost curve methodology are: 1) a list of policy measures capable of reducing greenhouse gas emissions in 2020, 2) the cost per metric ton of CO_2e emissions for each policy in 2020, and 3) the expected CO_2e emission reductions of each policy in 2020. Did you compile a list of Buildings and Electric Supply sector policy measures capable of reducing greenhouse gas emissions in 2020, determine the cost per metric ton of CO_2e emissions for each policy in 2020, and determine the expected CO_2e emission reductions of each policy in 2020?

A. Yes.

Q. What Buildings and Electric Supply sector policy measures are capable of reducing greenhouse gas emissions in 2020?

A. The CECP lists the Buildings and Electric Supply sector policy measures that are capable of reducing greenhouse gas emissions in 2020 (attached as Exhibit EAS-6). The following policy measures are included in the marginal cost of GWSA compliance analysis presented in this testimony:

- Solar Thermal Market and additional renewable thermal market policies (CECP, Exhibit EAS-6, p.29-31; see also Exhibit EAS-12)
- Federal Appliance Standards (CECP, p.35-36)
- Deep Energy Retrofits (CECP, p.26-27)
- All Cost-Effective Energy Efficiency (CECP, p.18-19)
- Advanced Building Codes (CECP, p.20-22)
- Tree Retention (CECP, p.32-34)
- RPS Class I and Class I Solar Carve-Out (CECP, p.40-41)
- CEPS (CECP, p.47-48)
- Clean Energy Imports (CECP, p.45-46)

The following Buildings and Electric Supply sector policy measures are discussed in the CECP but are not included in the marginal cost of GWSA compliance analysis presented in this testimony:

- Regional Greenhouse Gas Initiative (RGGI) (CECP, p.42-43): No explicit emission reductions are expected for this policy in the CECP.
- Building Energy Rating and Labeling (CECP, p.23-25): No explicit emission reductions are expected for this policy in the CECP.
- Expanding Energy Efficiency to Commercial and Industrials Heating Oil (CECP, p.28): No emission reductions are expected from this policy in 2020.[9]
- RPS Class II and Alternative Portfolio Standard (CECP, p.40-41): No emission reductions are expected from this policy in 2020.
- More Stringent EPA Power Plant Rules (CECP, p.44): Emission reductions from the retirement of the Salem and Somerset plants, discussed in the CECP, and of Brayton Point, discussed in the Global Warming Solutions Act 5-Year Progress Report, are included in the AESC Base Case and, therefore, in the updated business-as-usual scenario used for this analysis (see Section 6 of my testimony).

Massachusetts' Buildings and Electric Supply sector emission reduction policies for 2020 are listed in Table 2, ordered from least to most expensive per metric ton. Cumulative emission reductions add each policy's emission reductions together with the reductions of all less-expensive policies.

[9] Personal communication, Tina Halfpenny, DOER, March 12, 2014.

Table 2. Massachusetts' Buildings and Electric Supply sector emission reduction policies in 2020

Rank by Cost	Policy	Cost (2013 $ / metric ton)	Program Savings (000 metric tons CO_2e)	Cumulative Savings (000 metric tons CO_2e)
1	Federal Appliance Standards	-$568	500	500
2	All Cost-Effective EE	-$480	4,903	5,403
3	Deep Energy Retrofits	-$458	193	5,596
4	Advanced Building Codes	-$91	1,500	7,096
5	Renewable Thermal Market	-$90	1,242	8,338
6	Tree Retention	-$3	40	8,378
7	RPS - Class I – no Tx	$48	1,899	10,278
8	CEPS w/out Transmission	$48	160	10,438
9	Clean Energy Imports	$52	6,959	17,397
10	RPS - Class I - Solar Carve-Out	$152	817	18,213
11	CEPS (1st Tx upgrade)	$306	1,137	19,350
12	CEPS (2nd Tx upgrade)	$263	1,137	20,488
13	CEPS (3rd Tx upgrade)	$228	2,274	22,762

Q. How did you model the emission reductions from Electric Supply sector policies in your assessment?

A. I created a spreadsheet model of the 2020 New England electric system, including load, generation by resource type, and Massachusetts versus other-five-New England state disaggregation (attached as Exhibit EAS-16 Revised). The model begins with a business-as-usual scenario in which Massachusetts holds energy efficiency programs steady at the 2013 level until 2030, and does not undertake any new policy-based emission reductions. Each Electric Supply sector policy is added in turn to the business-as-usual scenario, in order of a preliminary estimate of their costs per metric ton, from least to most expensive. As the effects of each policy are added, Massachusetts emissions change. Policies cause a combination of the following effects tracked in the model:

- Fewer GWhs of electricity generated in Massachusetts
- Fewer GWhs of electricity imported into Massachusetts
- Import of more zero-carbon generation into Massachusetts
- Decreased emissions rate for Massachusetts generation
- Decreased emissions rate for five-state generation imported into Massachusetts

All of these effects, alone and in combination, result in lower emissions in Massachusetts.

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Federal Appliance Standards policy in 2020?

A. The estimated cost of the Federal Appliance Standards policy for 2020 is -$568 per metric ton of CO_2e reduction—a net benefit. Like several other CECP strategies, Federal Appliance Standards result in "negative costs", or net benefits: The monetized benefits of this policy are greater than the monetized costs. The expected CO_2e reduction of this policy is 500 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-6.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the All Cost-Effective Energy Efficiency policy in 2020?

A. The estimated cost of the All Cost-Effective Energy Efficiency policy for 2020 is -$480 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 4,903 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-13, Exhibit EAS-17, and Exhibit EAS-18.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Deep Energy Retrofits policy in 2020?

A. The estimated cost of the Deep Energy Retrofits policy for 2020 is -$458 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 193 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-13.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Advanced Building Codes policy in 2020?

A. The estimated cost of the Advanced Building Codes policy for 2020 is -$91 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 1,500 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-6.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Solar Thermal Market policy in 2020?

A. The Global Warming Solutions Act 5-Year Progress Report (attached as Exhibit EAS-12) expands the CECP's Solar Thermal Market policy to include thermal energy from a variety of renewable resources. A 2014 Report commissioned by DOER details the costs and emission reductions of this expanded policy (attached as Exhibit EAS-19). The estimated cost of the Renewable Thermal Market policy for 2020 is -$90 per metric ton of CO2e reduction—a net benefit. The expected CO_2e reduction of this policy is 1,242 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-20 and Exhibit EAS-21 Revised.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Tree Retention policy in 2020?

A. The estimated cost of the Tree Retention policy for 2020 is -$3 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 40 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-22.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the RPS policy in 2020?

A. The estimated cost of the RPS Class I policy for 2020 is $48 per metric ton of CO_2e reduction—a net cost. No transmission upgrades are necessary to comply with RPS Class I in 2020. The expected CO_2e reduction of this policy is 1,899 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-2.)

The estimated cost of the RPS Class I Solar Carve-Out policy for 2020 (including both SREC-1 and SREC-2) is $152 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 817 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-23.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the CEPS policy in 2020?

A. CEPS is a portfolio standard that provides a Clean Energy Certificate (CEC) incentive for additional clean resources, beyond those required by Renewable Portfolio Standard (RPS) Class I. I assume that the resources receiving CECs would be installed within New England; new Canada resources are included in the Clean Energy Import strategy discussed below. While CEPS in this analysis is addressing within-New England resources, conceptually a CEPS could address resources both within and imported to New England. In 2030, CEPS generation would require both the equivalent of the 2030 Class I REC projected in AESC 2013 and significant new investment in transmission as projected by ISO-NE.

For this analysis I divide the CEPS policy into two planks:

- New renewables relying on a Clean Energy Certificate (CEC) incentive that do not need a transmission upgrade to connect to load centers.
- New renewables relying on a CEC incentive that do need a transmission upgrade to connect to load centers. This second plank is further subdivided into three blocks of transmission upgrades: first, second, and third. The first, second, and third blocks of transmission must be implemented in this order. Because of economies of scale, this means that the first block is the most expensive and the third block is the least expensive. I assume that no offshore wind that is not already in the ISO-NE queue in 2014 can be brought on line by 2020.

The estimated cost of the CEPS policy for 2020 with no transmission upgrade necessary is $48 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 160 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

The estimated cost of the CEPS policy for 2020 with the first block of transmission upgrades is $306 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 1,137 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

The estimated cost of the CEPS policy for 2020 with the second block of transmission upgrades is $263 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 1,137 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

The estimated cost of the CEPS policy for 2020 with the third block of transmission upgrades is $228 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 2,274 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2020 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

Because solar resources require additional incentives beyond a Class I REC or CEC, and expected increments to generation from other renewable resources are, at present, marginal, I assume that the expected availability of and transmission costs associated with wind resources in New England adequately represents the availability and transmission costs associated with all new renewables. The estimated costs of transmission and the amount of generation from New England renewables available for the CEPS policy come from the New England Governors' *New England 2030 Power System Study* (attached as Exhibit EAS-25) and the ISO New England's *Wind Integration Study* (attached as Exhibit EAS-24), respectively, which rely on analysis conducted in 2009.

There have been no additional comprehensive analyses of large-scale wind integration in New England released in the intervening years. The majority of recent related work has been conducted within the framework of ISO New England's "Strategic Transmission Analysis"—an ongoing project that is focused on transmission upgrades associated with large fossil unit retirements. This project has also begun to include analysis of large-scale wind integration. An expected result of new analysis is that as transmission upgrades planned to alleviate constraints associated with fossil unit retirements are implemented, the costs of the transmission upgrades required for large-scale wind integration will decline. For this reason, projected transmission costs are likely to be lower in new analyses, although how much lower is not yet known.

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Clean Energy Imports policy in 2020?

A. The estimated cost of the Clean Energy Imports policy for 2020 is $52 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 6,959 thousand metric tons. (Calculations used to develop these 2020 values are attached as Exhibit EAS-16 Revised.) Cost and savings assumptions for Clean Energy Imports are based on the following assumptions:

- Imported electricity from Canada is available at the market price plus the cost of transmission from the Canadian border to New England load centers; this energy does not require a REC incentive;
- Two 1,200 MW transmission lines could be constructed from the Canadian border to New England load centers by 2020.[10] An additional 1,200 MW transmission line could be constructed from the Canadian border to New England load centers by 2030 (see, for example, Exhibit EAS- 26);
- Expected imported energy on these lines is 18,600 GWh in 2020 and 27,800 GWh in 2030, and all of this electricity is exclusively allocated to Massachusetts; and
- The levelized costs of these lines are $361 million in 2020 and $618 million in 2030, assuming a 30-year book life and a real discount rate of 5.1 percent.

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[10] For example, Massachusetts House Bill 3968 *An Act relative to clean energy resources* includes a value of 18,900,000 MWh, or 2,400 megawatts operating at 90-percent capacity over 8,760 hours each year.

Q. Have you assembled all four components necessary to determining the cost of 2020 GWSA compliance?

A. Yes.

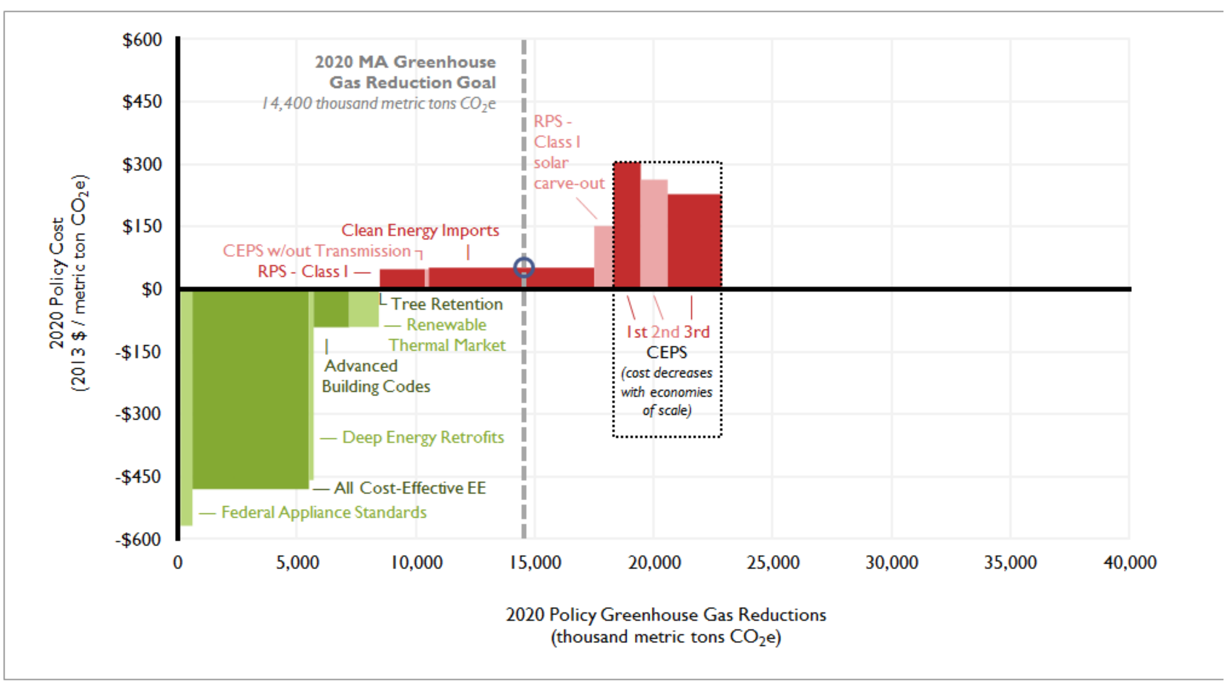
Q. As described above, the three steps to completing a marginal abatement cost curve analysis are: (A) place policy options in order by their cost per metric ton; (B) add policies one by one, from least to most expensive, until policy emission reductions are sufficient to comply with GWSA requirements; and (C) identify the most expensive policy needed for GWSA compliance as the marginal policy and its cost as the cost of GWSA compliance. Did you take the three steps necessary to complete a marginal abatement cost curve analysis and determine the cost of GWSA compliance in 2020?

A. Yes. These calculations are shown in Exhibit EAS-16 Revised.

Q. Did you develop a graphical depiction of the "marginal abatement cost curve" for 2020 GWSA compliance?

A. Yes. This graph was developed in Exhibit EAS-16 Revised and is attached as Exhibit EAS-27 Revised and shown here as Figure 3.

Figure 3. Massachusetts marginal abatement cost curve for GWSA compliance, 2020



The marginal policy for 2020 is Clean Energy Imports at $52 per metric ton CO_2e, in 2013 dollars. Source: DPU 2-2 Exhibit 2

Q. What is the "marginal" policy (or most expensive policy necessary) for achieving the 14.4 million metric ton policy-based emission reduction needed for GWSA compliance in 2020?

A. The marginal policy for 2020 GWSA compliance is Clean Energy Imports, which is the import of hydroelectric generation from Canada using new transmission lines. The incremental cost of this policy (above conventional generation) needed to bring these Canadian resources to New England load centers is based on the assumptions discussed above in Section 7, and on the levelized cost of the new transmission needed to bring these Canadian resources to New England load centers.

Q. What is the estimated cost per metric ton of CO_2e reduction of the Clean Energy Imports policy in 2020?

A. The estimated cost of the Clean Energy Imports policy in 2020 is $52 per metric ton of CO_2e reduction.

Q. What, therefore, is the estimated cost of GWSA compliance in 2020?

A. The estimated cost of GWSA compliance in 2020 is the estimated cost of the marginal policy for GWSA compliance, Clean Energy Imports: $52 per metric ton of CO_2e. This cost per metric ton translates into $20 per MWh, $0.28 per therm, and $3.8 per MMBtu avoided costs applied to energy efficiency as discussed below in Section 10.

8. <u>POLICY-BASED EMISSION REDUCTIONS NECESSARY FOR 2030 GWSA COMPLIANCE</u>

Q. Have you made an assessment of the policy-based emission reductions necessary for 2030 GWSA compliance?

A. Yes.

Q. Why do you assess emission reductions for 2030?

A. After 2020, 2030 is the next major milestone noted in the GWSA, which requires that a 2030 interim emissions limit be set that "maximizes the ability of the Commonwealth to meet the 2050 emissions limit." (see M.G.L. c. 21N, Climate Protection and Green

Economy Act). It is necessary to estimate the 2030 GWSA compliance costs at this time because the energy efficiency resources implemented in the next several years will operate well past 2020 and thus provide an opportunity to reduce GWSA compliance costs in the years after 2020. There are relatively few energy efficiency resources that, if installed in the next few years, would have savings well past 2030.

Q. What greenhouse gas emission reduction does the GWSA require for 2030?

A. No 2030 emission reduction requirement has yet been set for GWSA compliance. However, a linear interpolation between the 2020 and 2050 GWSA emission reduction requirements would be a reasonable way to approximate 2030 requirements.[11] Using this method, GWSA compliance requires a 43-percent statewide emission reduction from 1990 statewide emissions in 2030. The framework recommended in this testimony, including this 2030 estimate, can and should be periodically updated as additional or updated information becomes available.

Q. Given a 43-percent statewide emission reduction requirement for GWSA compliance in 2030, what assumptions are needed to estimate the emission reductions necessary in the Buildings and Electric Supply sectors?

A. As discussed below, I estimate 2030 business-as-usual emissions for the Buildings and Electric Supply sectors, I assume that 2030 business-as-usual emissions for the Transportation and Non-Energy sectors will be identical to the 2020 CECP business-as-usual projections for those sectors, and I assume the same allocation of policy-based emission reductions across sectors as is called for in CECP for 2020. The framework recommended in this testimony, including sectoral allocation of reductions, can and should be periodically updated as additional or updated information becomes available.

[11] The Department used linear interpolation to estimate the GWSA emission reduction targets when it approved long-term contracts for the purchase of windpower and renewable energy certificates. *See Petition of Massachusetts Electric Company and Nantucket Electric Company, each dba National Grid, for approval by the Department of Public Utilities of two long-term contracts to purchase wind power and renewable energy certificates pursuant to St. 2009, c. 169, § 83 and 220 C.M.R. § 17.00*, D.P.U. 10-54, Final Order, p. 174, footnote 150 (November 22, 2010).

Q. Do you consider the sensitivity of the calculated cost of 2030 GWSA compliance to the assumption that the allocation of policy-based emission reductions across sectors will be the same in 2030 as it was in 2020?

A. Yes. I discuss the results of this sensitivity analysis below in Section 10. In brief, I allocate 64-percent of all policy-based emission reductions in 2030 to the Buildings and Electric Supply sectors, based on the sectoral allocation of policy-based emission reductions for 2020 assumed in the CECP. The sensitivity analysis that I perform examines what changes in the sectoral allocation of policy-based emission reductions would be necessary to shift to a new marginal policy for 2030 GWSA compliance and, therefore, a new estimate of the 2030 GWSA compliance cost. Buildings and Electric Supply sector allocations of 44 to 68 percent result in Clean Energy Imports policy as the 2030 marginal policy. A change to a 43-percent allocation to these sectors shifts the marginal policy to Tree Retention and a lower estimated cost of GWSA compliance. A change to a 69-percent allocation to these sectors shifts the marginal policy to RPS Class I and a higher estimated cost of GWSA compliance.

Q. Have you made projections of 2030 business-as-usual greenhouse gas emissions in the Buildings and Electric Supply sectors?

A. Yes.

Q. How did you project 2030 business-as-usual emissions in the Electric Supply sector?

A. For the Electric Supply sector, I multiplied a projected 2030 business-as-usual emissions rate for New England generation (including imports) by projected 2030 business-as-usual retail electric sales for Massachusetts.

The business-as-usual emissions rate was calculated using the 2028 (the final year in AESC 2013 modeling) generation and imports resource mix for New England used in AESC 2013, which includes expected fuel price changes, retirements and additions, and an expected load holding efficiency measures steady at their 2013 level until 2028. I adjusted the 2030 resource mix to remove all renewable resources constructed after Massachusetts' RPS came into effect in 2008; renewables were replaced with natural gas generation—assumed to be the marginal resource in New England—to maintain the same generation level. I use the AESC 2013 emission rates by resource, but estimate a New England average emission rate that is higher than that of AESC 2013 due to additional generation from natural gas.

Massachusetts' 2030 business-as-usual load was assumed to be the ISO-NE 2012 CELT Base forecast (attached as Exhibit EAS-11) for 2021 that excludes energy efficiency escalated to 2030 using the CELT's 2017 to 2021 average growth rate. This projected load is adjusted to remove the load reductions associated with increasingly stringent Federal Appliance standards (see Exhibit EAS-11 tab 9 and Exhibit EAS-13) and then escalated slightly to account for behind-the-meter solar generation constructed after 2008 (which is replaced with natural gas generation).

Based on these assumptions, which are similar to those used for the 2020 business-as-usual calculation, I project that the 2030 business-as-usual emissions in the Electric Supply sector will be 25.3 million metric tons of CO_2e (calculations attached as Exhibit EAS-16 Revised).

Q. How did you project 2030 business-as-usual emissions in the Buildings sector?

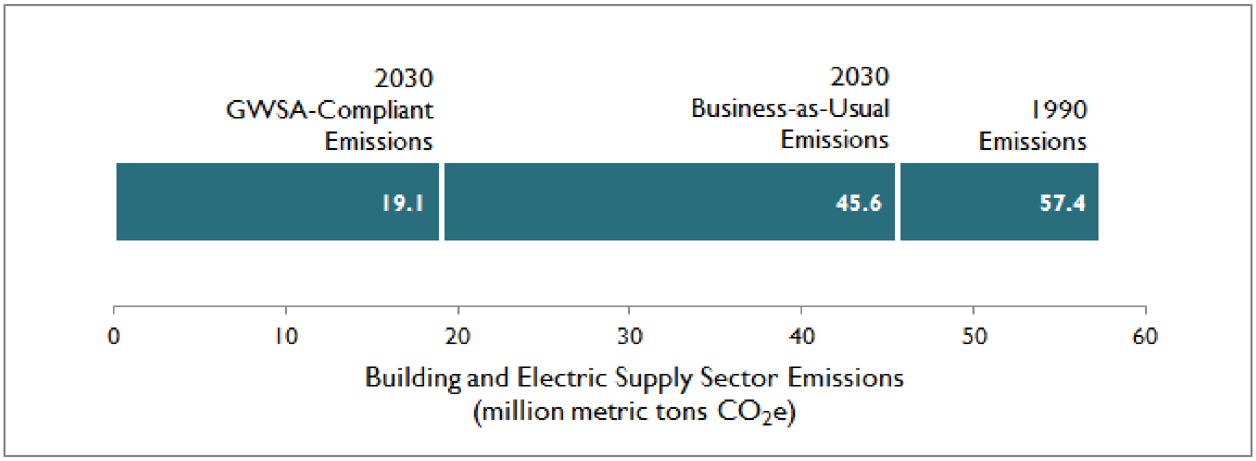
A. For the Buildings sector, I escalate the 2020 Massachusetts' emissions from Building-sector natural gas and fuel oil use (described above in Section 7) using the 2021 to 2030 EIA annual growth rates for natural gas and fuel oil in their "2012 Demand Technology Case": natural gas, 0.5 percent; and fuel oil, -1.1 percent.

Based on these assumptions, I project that the 2030 business-as-usual emissions in the Buildings sector will be 20.3 million metric tons of CO_2e (calculations attached as Exhibit EAS-14)

Q. What is your projection of Massachusetts' 2030 business-as-usual greenhouse gas emissions in the combined Buildings and Electric Supply sectors?

A. Based on these 2030 business-as-usual forecasts—Buildings 20.3 million metric tons, and Electric Supply 25.3 million metric tons—I project Buildings and Electric Supply 2030 business-as-usual emissions to be 45.6 million metric tons (calculations attached as Exhibit EAS-8) as shown in Figure 4.

Figure 4. Massachusetts Buildings and Electric Supply sector 1990 emissions, 2030 business-as-usual emissions, and 2030 GWSA-compliant emissions



Q. What is the difference between 1990 Buildings and Electric Supply sector emissions and your projections of 2030 business-as-usual greenhouse gas emissions for these sectors?

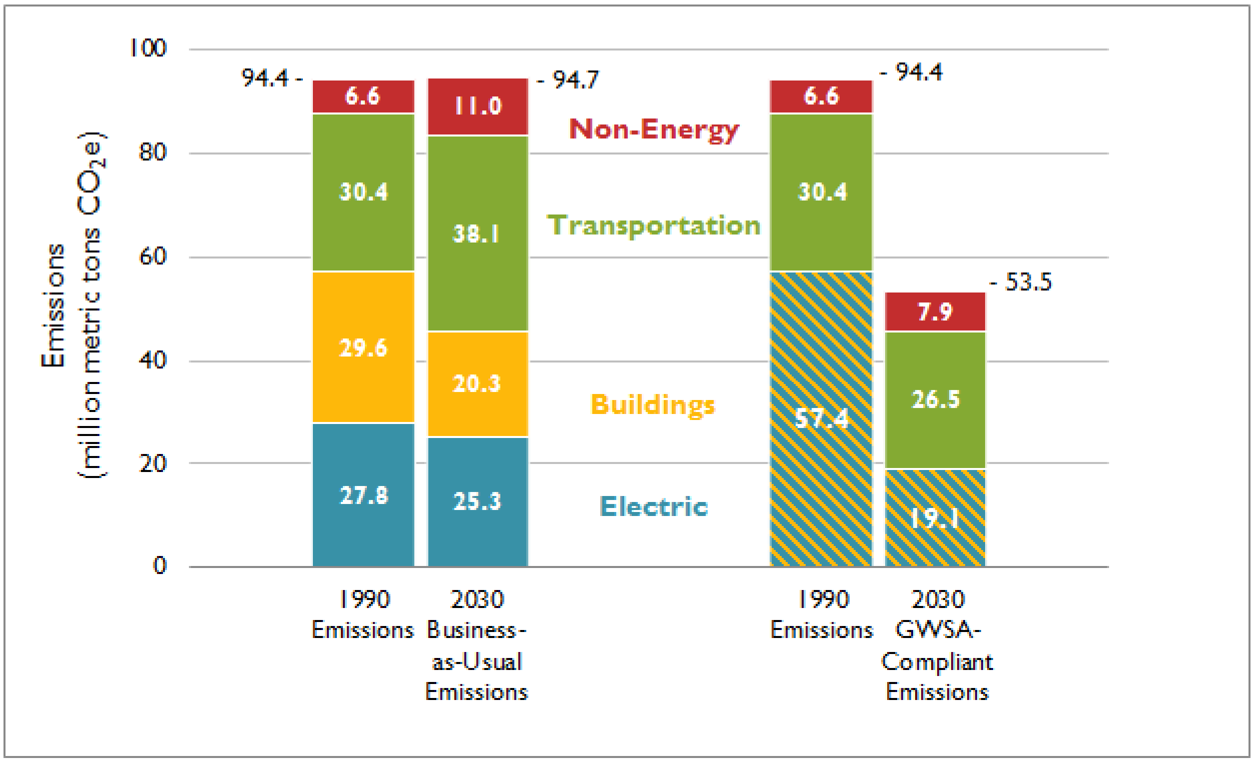
A. The difference between 1990 emissions (57.4 million metric tons CO_2e) and 2030 business-as-usual projected emissions in the Buildings and Electric Supply sectors (45.6 million metric tons) is 11.9 million metric tons (calculations attached as Exhibit EAS-8).

Q. What statewide 2030 business-as-usual emission reduction is implied by this business-as-usual projection for the Buildings and Electric Supply sectors?

A. Assuming that business-as-usual emissions in the Transportation and Non-Energy sectors remain constant from 2020 to 2030, and using this 2030 business-as-usual projection for the Buildings and Electric Supply sectors, statewide 2030 business-as-usual emissions are projected to be 94.7 million metric tons CO_2e: the sum of the business-as-usual Buildings and Electric Supply sector projection for 2030 (45.6 million metric tons), the CECP business-as-usual Transportation sector projection (38.1 million metric tons), and the CECP business-as-usual Non-Energy sector projection (11.0 million metric tons).

The difference between 1990 statewide emissions (94.4 million metric tons) and updated statewide 2030 business-as-usual projected emissions (94.7 million metric tons) is -0.3 million metric tons (calculations attached as Exhibit EAS-8) as shown in Figure 5. Buildings and Electric Supply sector emissions for 2030 GWSA compliance are combined in Figure 5 because the CECP includes several policies that affect both sectors jointly.

Figure 5. Massachusetts 1990 emissions, 2030 business-as-usual emissions, and 2030 GWSA compliant emissions



Q. Based on your projection of business-as-usual greenhouse gas emissions for 2030, what policy-based emission reductions are necessary for 2030 GWSA compliance in the Buildings and Electric Supply sectors?

A. Statewide policy-based emission reductions are the difference between the projected statewide 2030 GWSA emission reduction target (43-percent below 1990 levels, or 40.9 million metric tons CO_2e) and statewide business-as-usual emission changes (-0.3 million metric tons—an increase). Projected statewide policy-based emission reductions required for GWSA compliance in 2030 are, therefore, 41.2 million metric tons.

I allocate policy-based reductions to each of the four economic sectors in proportion to the share of 2020 policy-based emission reductions from each sector reported in the CECP: Buildings and Electric Supply sectors, 64 percent; Transportation sector, 28 percent; and Non-Energy sector, 7 percent (calculations attached as Exhibit EAS-8).

The projected 2030 policy-based emission reduction required for the Buildings and Electric Supply sectors combined is 26.5 million metric tons (calculations attached as Exhibit EAS-8).

9. DEMONSTRATION OF COST OF 2030 GWSA COMPLIANCE METHODOLOGY

Q. As described above, the first component in the marginal abatement cost curve methodology is the amount of emission reductions required in 2030 for GWSA compliance. What amount of Buildings and Electric Supply sector emission reductions did you determine was required in 2030 for GWSA compliance?

A. The policy-based emission reduction necessary from the Buildings and Electric Supply sectors for 2030 GWSA compliance is 26.5 million metric tons CO_2e.

Q. As described above, the other three components in the marginal abatement cost curve methodology are: 1) a list of policy measures capable of reducing greenhouse gas emissions in 2030, 2) the cost per metric ton of CO_2e emissions for each policy in 2030, and 3) the expected CO_2e emission reductions of each policy in 2030. Did you compile a list of Buildings and Electric Supply sector policy measures capable of reducing greenhouse gas emissions in 2030, determine the cost per metric ton of CO_2e emissions for each policy in 2030, and determine the expected CO_2e emission reductions of each policy in 2030?

A. Yes.

Q. What Buildings and Electric Supply sector policy measures are capable of reducing greenhouse gas emissions in 2030?

A. The CECP lists the Buildings and Electric Supply sector policy measures that are capable of reducing greenhouse gas emissions in 2020 (attached as Exhibit EAS-6). The following measures can provide emission reductions in 2030 and therefore are included in the marginal cost of 2030 GWSA compliance analysis presented in this testimony:

- Renewable Thermal Market (CECP, p.29-31, Exhibit EAS-6; see also Exhibit EAS-12)
- Federal Appliance Standards (CECP, p.35-36)
- Deep Energy Retrofits (CECP, p.26-27)
- All Cost-Effective Energy Efficiency (CECP, p.18-19)
- Advanced Building Codes (CECP, p.20-22)
- Tree Retention (CECP, p.32-34)
- RPS Class I (CECP, p.40-41)
- CEPS (CECP, p.47-48)
- Clean Energy Imports (CECP, p.45-46)

Massachusetts' Buildings and Electric Supply sector emission reduction policies for 2030 are listed in Table 3.

Table 3. Massachusetts' Buildings and Electric Supply sector emission reduction policies in 2030

		Cost (2013 $ / metric ton)	Program Savings (000 metric tons CO_2e)	Cumulative Savings (000 metric tons CO_2e)
1	All Cost-Effective EE	-$480	8,219	8,219
2	Deep Energy Retrofits	-$464	191	8,409
3	Federal Appliance Standards	-$390	1,569	9,978
4	Advanced Building Codes	-$91	1,500	11,478
5	Renewable Thermal Market	-$90	5,805	17,284
6	Tree Retention	-$3	111	17,395
7	Clean Energy Imports	$59	10,437	27,832
8	RPS - Class I – no Tx	$75	2,184	30,017
9	Former Class I - Solar Carve-Out	$152	803	30,820
10	RPS - Class I – with Tx	$337	1,744	32,564
11	CEPS (1st Tx upgrade)	$337	411	32,974
12	CEPS (2nd Tx upgrade)	$294	2,236	35,211
13	CEPS (3rd Tx upgrade)	$258	4,473	39,684

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the All Cost-Effective Energy Efficiency policy in 2030?

A. I project All Cost-Effective Energy Efficiency emission reductions to 2030 assuming that annual first-year savings will remain constant as a share of retail sales from 2020 to 2030 at 2.9 percent. I assume a 13-year measure lifetime with measures retiring at the end of this lifetime, but 25-percent savings from end-of-life measures replaced without incentive (see calculations attached as Exhibit EAS-13).

The estimated cost of the All Cost-Effective Energy Efficiency policy for 2030 is -$480 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 8,219 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using data from Exhibit EAS-13, Exhibit EAS-17, and Exhibit EAS-18.)

Q. Do you consider the sensitivity of the calculated cost of 2030 GWSA compliance to the assumption that first-year energy efficiency savings as a share of sales remain constant from 2020 to 2030?

A. Yes. I discuss the results of this sensitivity analysis below in Section 10. In brief, the sensitivity analysis that I perform examines what changes in first-year energy efficiency savings as a share of sales would be necessary to shift to a new marginal policy for 2030 GWSA compliance and, therefore, a new 2030 cost of GWSA compliance. First-year energy efficiency savings as a share of retail sales of 2.2 to 6.8 percent result in Clean Energy Imports policy as the 2030 marginal policy. A change to a 6.9-percent share of retail sales shifts the marginal policy to Tree Retention and a lower estimated cost of GWSA compliance. A change to a 2.1-percent share of retail sales shifts the marginal policy to RPS Class I and a higher estimated cost of GWSA compliance.

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Deep Energy Retrofits policy in 2030?

A. The estimated cost of the Deep Energy Retrofits policy for 2030 is -$464 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 191 thousand metric tons. (Calculations used to develop these values are attached as Exhibit

EAS-16 Revised assuming that the 2020 assumptions in Exhibit EAS-13 remain constant to 2030.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Federal Appliance Standards policy in 2030?

A. The estimated cost of the Federal Appliance Standards policy for 2030 is -$390 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 1,569 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-6 and Exhibit EAS-28, from the American Council for an Energy-Efficient Economy and Appliance Standards Awareness Project, the same organization used in the CECP for the 2020 assumptions regarding this policy. Exhibit EAS-28 is a 2012 update to the document used to develop the CECP.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Advanced Building Codes policy in 2030?

A. The estimated cost of the Advanced Building Codes policy for 2030 is -$91 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 1,500 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised assuming that the 2020 assumptions in Exhibit EAS-6 remain constant to 2030.) This is a conservative assumption, based on the potential for savings from Advanced Building Codes to overlap with All Cost-Effective Energy Efficiency and the Renewable Thermal Market emissions savings in the 2020-2030 time period.[12]

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Renewable Thermal Market policy in 2030?

A. The estimated cost of the Renewable Thermal Market policy for 2030 is -$90 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 5,805 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-20 and Exhibit EAS-21 Revised.)

[12] Personal communication, Ian Finlayson, DOER, May 14, 2014.

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Tree Retention policy in 2030?

A. The estimated cost of the Tree Retention policy for 2030 is -$3 per metric ton of CO_2e reduction—a net benefit. The expected CO_2e reduction of this policy is 111 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using data from Exhibit EAS-22.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the Clean Energy Imports policy in 2030?

A. The estimated cost of the Clean Energy Imports policy for 2030 is $59 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 10,437 thousand metric tons. (Calculations used to develop these 2030 values are attached as Exhibit EAS-16 Revised based on the assumptions discussed in Section 7 above.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the RPS policy in 2030?

A. I separate resources built with RPS Class I REC incentives into those that are built before transmission upgrades are needed to add new renewable generation in New England, and those that are built after transmission upgrades become necessary. The estimated amount of generation from New England renewables available without a transmission upgrade comes from the ISO New England's *Wind Integration Study* (attached as Exhibit EAS-24).

The estimated cost of the RPS Class I policy for 2030 for those resources that are built before transmission upgrades are needed to add new renewable generation in New England is the 2030 Class I REC value. The estimated cost of the RPS Class I policy without transmission upgrades is $75 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 2,184 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-4 and Exhibit EAS-24.)

The estimated cost of the RPS Class I policy for 2030 for those resources that are built after transmission upgrades are needed to add new renewable generation in New England includes both the 2030 Class I REC value and the estimated cost of the transmission upgrades necessary to allow new resources sufficient to fulfill the Class I requirement. The estimated cost of the RPS Class I policy is $337 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 1,744 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

RPS Class I Solar Carve-Out is phased out by 2030. The resources installed under the SREC programs receive Class I RECs beginning ten years after their installation. The former Class I Solar Carve-Out resources are, however, included in this 2030 analysis separately from Class I resources because their lifetime costs are different; in effect, the former Class I Solar Carve-Out is a portion of total Class I emission reductions in 2030. The cost of the former RPS Class I Solar Carve-Out policy for 2030 is $152 per metric ton of CO2e reduction—a net cost. The expected CO2e reduction of this policy is 803 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-23.)

Q. What are the estimated cost per metric ton of CO_2e emissions and the expected CO_2e emission reductions of the CEPS policy in 2030?

A. All CEPS resources require transmission upgrades in 2030. New renewables will rely both on a CEC incentive and a transmission upgrade to connect to load centers. CEPS resources are divided into three blocks of transmission upgrades: first, second, and third. The first, second, and third blocks of transmission must be implemented in this order. Because of economies of scale, this means that the first block is the most expensive and the third block is the least expensive.

The estimated cost of the CEPS policy for 2030 with the first block of transmission upgrades is $337 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 411 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

The estimated cost of the CEPS policy for 2030 with the second block of transmission upgrades is $294 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 2,236 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

The estimated cost of the CEPS policy for 2030 with the third block of transmission upgrades is $258 per metric ton of CO_2e reduction—a net cost. The expected CO_2e reduction of this policy is 4,473 thousand metric tons. (Calculations used to develop these values are attached as Exhibit EAS-16 Revised using 2030 data from Exhibit EAS-4, Exhibit EAS-24 and Exhibit EAS-25.)

As discussed above, projected transmission costs are likely to be lower in new analyses, although how much lower is not yet known.

Q. Do the greenhouse gas reductions from the modeled policies ever exceed the total possible greenhouse gas reductions?

A. Yes, but only in the Electric Supply sector. In 2030, using the policies as modeled, it is not possible to simultaneously implement all of the policies shown in the marginal abatement cost curve because electric sector emissions would drop below zero. Achievable reductions are exhausted part way through the second CEPS transmission block. If the Clean Energy Imports strategy were not implemented, however, then the full CEPS policy would be achievable. The marginal policy in 2030 is reached before electric sector emissions are reduced to zero; therefore this issue is not a limitation to the results of this analysis. This possibility should be kept in mind in reviewing the results of any future update to the framework recommended in this testimony.

Q. Have you assembled all four components necessary to determining the cost of 2030 GWSA compliance?

A. Yes.

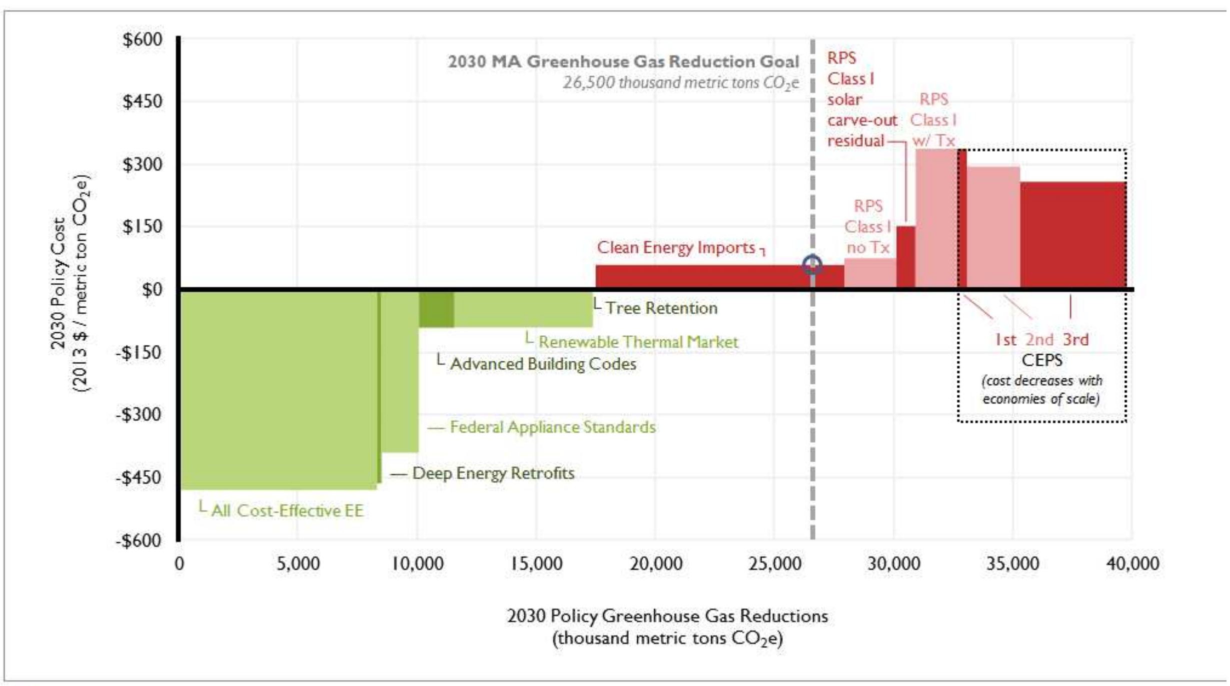
Q. As described above, the three steps to completing a marginal abatement cost curve analysis are: (A) place policy options in order by their cost per metric ton; (B) add policies one by one, from least to most expensive, until policy emission reductions are sufficient to comply with GWSA requirements; and (C) identify the most expensive policy needed for GWSA compliance as the marginal policy and its cost as the cost of GWSA compliance. Did you take the three steps necessary to complete a marginal abatement cost curve analysis and determine the cost of GWSA compliance in 2030?

A. Yes. These calculations are shown in Exhibit EAS-16 Revised.

Q. Did you develop a graphical depiction of the "marginal abatement cost curve" for 2030 GWSA compliance?

A. Yes. This graph was developed in Exhibit EAS-16 Revised and is attached as Exhibit EAS-29 Revised and shown here as Figure 6.

Figure 6. Massachusetts marginal abatement cost curve for GWSA compliance, 2030



The marginal policy for 2030 is Clean Energy Imports at $59 per metric ton CO_2e, in 2013 dollars. Source: DPU 2-2 Exhibit 2

Q. What is the "marginal" (or most expensive policy necessary) for achieving the 26.5 million ton policy-based emission reduction needed for GWSA compliance in 2030?

A. The marginal policy for 2030 GWSA compliance is Clean Energy Imports, which is the import of hydroelectric generation from Canada using new transmission lines. The incremental cost of this policy (above conventional generation) is based on the assumptions discussed above in Section 7, and is based on the levelized cost of the new transmission needed to bring these Canadian resources to New England load centers.

Q. What is the estimated cost per metric ton of CO_2e reduction of the Clean Energy Imports policy in 2030?

A. The estimated cost of the Clean Energy Imports policy in 2030 is $59 per metric ton of CO_2e reduction.

Q. What, therefore, is the estimated cost of GWSA compliance in 2030?

A. The estimated cost of GWSA compliance in 2030 is the estimated cost of the marginal policy for GWSA compliance, Clean Energy Imports: $59 per metric ton of CO_2e.

10. RECOMMENDED GWSA COMPLIANCE COSTS

Q. How should the cost per metric ton value of GWSA compliance be applied to the electricity, gas, and oil savings of Massachusetts energy efficiency programs?

A. For electricity efficiency savings, the estimated cost per metric ton value of GWSA compliance must be converted to dollars per MWh. I assume a New England marginal emissions rate of 0.38 metric tons CO_2e per MWh for this purpose (the emissions rate for non-cogenerating natural gas in New England; see Exhibit EAS-16 Revised and AESC 2013 attached as Exhibit EAS-2).

For gas and oil efficiency savings, compliance cost values must be converted to dollars per therm and dollars per MMBtu, respectively. I assume the following emission rates for this purpose: gas (0.005311 metric tons CO_2e per therm); and oil (0.073204 metric tons

CO_2e per MMBtu).[13] Table 4 reports the GWSA compliance costs for 2020 and 2030 in metric tons, and the corresponding costs for MWh of electric generation, therms of natural gas, and MMBtu of heating oil (as shown in Exhibit EAS-16 Revised). Also in Table 4, for purposes of comparison, is the 2020 cost of GWSA compliance reported in AESC 2013, p.4-60.

Table 4. 2020 and 2030 GWSA compliance costs compared to 2020 GWSA compliance cost estimated in AESC 2013

Unit	2020 (per 2013 AESC)	2020	2030
2013 $ / metric ton	$48	$52	$59
2013 $ / MWh	$18	$20	$23
2013 $ / therm natural gas	$0.26	$0.28	$0.31
2013 $/ MMBtu heating oil	$3.5	$3.8	$4.3

Q. Do you calculate the levelized cost of GWSA compliance?

A. Yes, these calculations are developed in Exhibit EAS-16 Revised and presented in Table 5. To calculate a levelized cost, I assume the following: a) the most recent RGGI clearing price—$5.30 per metric ton in 2014—as reported in RGGI Auction 25 (attached as Exhibit EAS-31), b) a linear trend from this 2014 value to the estimate marginal cost of compliance with GWSA in 2020, c) a linear trend from 2020 to 2030, and d) constant costs from 2030-2034, and e) a real discount rate of 1.36 percent as used in AESC 2013, Appendix B.

[13] These emission rates are taken from the EIA's Table A.3 Carbon Dioxide Uncontrolled Emission Factors (attached as Exhibit EAS-30) and are converted in Exhibit EAS-10 from 117.08 lbs. CO_2 per MMBtu natural gas and 161.386 lbs. CO_2 per MMBtu distillate fuel oil to the values in metric tons CO_2e per therm and per MMBtu shown above.

Table 5. Annual and levelized cost of GWSA compliance

	2013 $ / metric ton	2013 $ / MWh	2013 $ / therm	2013 $ / MMBtu
2014	$5	$2	$0.03	$0.4
2015	$13	$5	$0.07	$1.0
2016	$21	$8	$0.11	$1.5
2017	$29	$11	$0.15	$2.1
2018	$36	$14	$0.19	$2.7
2019	$44	$17	$0.23	$3.2
2020	$52	$20	$0.28	$3.8
2021	$53	$20	$0.28	$3.9
2022	$54	$20	$0.28	$3.9
2023	$54	$21	$0.29	$4.0
2024	$55	$21	$0.29	$4.0
2025	$56	$21	$0.30	$4.1
2026	$56	$22	$0.30	$4.1
2027	$57	$22	$0.30	$4.2
2028	$58	$22	$0.31	$4.2
2029	$59	$22	$0.31	$4.3
2030	$59	$23	$0.31	$4.3
2031	$59	$23	$0.31	$4.3
2032	$59	$23	$0.31	$4.3
2033	$59	$23	$0.31	$4.3
2034	$59	$23	$0.31	$4.3
10-year levelized cost (2015-2024)	$40	$15	$0.21	$3.0
15-year levelized cost (2015-2029)	$46	$17	$0.24	$3.3
20-year levelized cost (2015-2034)	$49	$19	$0.26	$3.6

Q. What was the result of the sensitivity analysis that you performed on the impact of the assumption that a 25-percent reduction in statewide greenhouse gas emissions in 2020 is required, rather than the 27.3-percent reduction used in the CECP?

A. I analyzed the impact of changing the assumed total statewide greenhouse gas emission reduction in 2020 from 25-percent (as required by the GWSA) to 27.3-percent (the combined business-as-usual and policy-based reductions called for the CECP). This adjustment would change the 2020 GWSA-compliant emission reduction target from 14.4 million metric tons CO_2e to 15.8 million metric tons. This change in target would have no impact on the marginal policy in 2020 and, therefore, no impact on the cost of 2020 GWSA compliance. This analysis is shown in Exhibit EAS-16 Revised.

Q. What was the result of the sensitivity analysis that you performed on the impact of the assumption that the allocation of policy-based emission reductions by sector would remain constant from 2020 to 2030?

A. In the CECP, the Buildings and Electric Supply sectors are responsible for 64 percent of policy-based emission reductions in 2020. I analyzed the impact of changes to the assumption that allocation of policy-based emission reductions by sector would remain constant from 2020 to 2030. My findings were as follows:

- To change the 2030 marginal policy to Tree Retention it would be necessary to reduce the Buildings and Electric Supply sectors' allocation to 43 percent. This change would reduce the cost of 2030 GWSA compliance from $59 per metric ton of CO_2e to -$3 per metric ton.
- To change the 2030 marginal policy to former RPS Class I with no transmission upgrades it would be necessary to increase the Buildings and Electric Supply sectors' allocation to 69 percent. This change would increase the cost of 2030 GWSA compliance to $75 per metric ton. This analysis is shown in Exhibit EAS-16 Revised.

Q. What was the result of the sensitivity analysis that you performed on the impact of the assumption that first-year energy efficiency savings as a share of sales remains constant from 2020 through 2030?

A. I analyzed the impact of adjusting the assumed first-year energy efficiency savings as a share of sales from 2020 to 2030. My findings were as follows:

- To change the 2030 marginal policy to Tree Retention it would be necessary to increase the share of sales from 2.9 percent to 6.9 percent. This change would reduce the cost of 2030 GWSA compliance from $59 per metric ton of CO_2e to -$3 per metric ton.

- To change the 2030 marginal policy to the former RPS Class I with no transmission upgrades it would be necessary to decrease the growth rate from 2.9 percent to 2.1 percent. This change would increase the cost of 2030 GWSA compliance to $75 per metric ton. This analysis is shown in Exhibit EAS-16 Revised.

Q. What is the cost of 2020 GWSA compliance?

A. The cost of compliance with GWSA in 2020 is $52 per metric ton of CO_2e, $20 per MWh, $0.28 per therm, and $3.8 per MMBtu.

Q. What is the cost of 2030 GWSA compliance?

A. The cost of compliance with GWSA in 2030 is $59 per metric ton of CO_2e, $23 per MWh, $0.31 per therm, and $4.3 per MMBtu.

Q. Does this conclude your pre-filed testimony?

A. Yes, it does.