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# Economic Impacts of S. 1733: The Clean Energy Jobs and American Power Act of 2009

## October 23, 2009

**U.S. Environmental Protection Agency**
**Office of Atmospheric Programs**

On September 30, 2009, Senators Kerry and Boxer introduced the Clean Energy Jobs and American Power Act of 2009 (S. 1733). The counterpart bill in the House of Representatives is the American Clean Energy and Security Act of 2009 (H.R. 2454), for which EPA developed cost estimates on June 23, 2009. This paper presents a discussion of how some of the key provisions in the Senate bill compare to the House bill, particularly with respect to the likely economic impacts of the bill. In order to produce this analysis, EPA synthesized the results of a significant volume of modeling analysis on economy-wide climate policy performed by the Agency. This effort drew from the nearly 50 modeling scenarios of five bills over the past two years, with particular focus on the two economic analyses of the Waxman-Markey bill this year. Through this effort, we carefully assessed the key differences and whether any would result in substantial changes to the modeled impacts.[1]

The assessment in this paper draws upon existing modeling by EPA that used full computable general equilibrium models (ADAGE and IGEM), as well as modeling that used reduced form versions of EPA's models. These models serve as stylized versions of the U.S. economy and climate change policy. In effectively simplifying the real-world in order for a modeling analysis to be computationally feasible, it is important to recognize that some minor differences between the policy designs in H.R. 2454 and S. 1733 are made irrelevant by the set-up of the models. This is not unique to the set of models employed by EPA, but common among the broader modeling community. Nonetheless, reviewing the breadth of the EPA modeling scenarios provides an opportunity to identify the most important, robust conclusions that models can illuminate about the design of climate policy.

EPA's assessment of the two bills indicates that the full suite of EPA models would likely show that the impacts of S. 1733 would be similar to those estimated for H.R. 2454. Four key messages from the EPA analysis of H.R. 2454 would remain unchanged: (1) the cap-and-trade policies outlined in these bills would transform the way the United States produces and uses energy; (2) the average loss in consumption per household will be relatively low, on the order of hundreds of dollars per year in the main policy case; (3) the impacts of climate policy are likely to vary comparatively little across geographic regions; and (4) what we assume about the actions of other countries has much greater implications for the overall impact of the policy than the modeled differences between the two bills.

That said, there are a few differences between S. 1733 and H.R. 2454 that could have a small impact on the modeled costs of the policy. First, the 2020 cap level in S. 1733 requires a 20% reduction from 2005 emissions levels instead of the 17% reduction required in H.R. 2454, although this is the same 2020 target as modeled in the April 2009 analysis of the Waxman-Markey discussion draft. Moving from a 17% to 20% target would raise costs slightly in the models. Second, S. 1733 allows landfill and coal mine $CH_4$ as offset sources, whereas H.R. 2454 instead subjected them to performance standards. This will lower costs slightly and result in a small increase in overall

[1] Note also that EPA's analysis did not examine the costs of not acting to reduce greenhouse gases nor does it compare the costs of S. 1733 against other policy approaches to address GHG emissions.



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emissions. Third, the market stability reserve allowance provisions in S. 1733 are changed to provide greater price certainty than the strategic reserve allowance provisions in H.R. 2454. S. 1733 also allocates more allowances to the market stability reserve than H.R. 2454 allocates to the strategic reserve. Assuming allowance prices remain low enough that covered entities do not purchase reserve allowances, this change will result in slightly higher costs in S. 1733 compared to H.R. 2454. For the most part the differences between the bills result in relatively small differences in estimated costs and may even cancel each other out on net.

There are many similarities between the bills. While the 2020 caps differ, the caps start out the same in 2012, and are identical between 2030 and 2050. Cumulatively, the caps differ by just one percent over four decades. Both of the bills cover the same sources of greenhouse gas emissions. Both bills place limits on offsets that are not expected to be binding. Both bills allow offsets from a broad array of agriculture and forestry sources. Both bills allow unlimited banking of allowances. Both bills have output-based rebate provisions designed to reduce emissions leakage and address competitiveness concerns for energy intensive and trade exposed industries. Because of these many similarities and the relatively small differences between the two bills, it is likely that a full analysis of S. 1733 would show economic impacts very similar to H.R. 2454.

EPA analysis mainly focuses on modeling the cap-and-trade policy outlined in proposed legislation. With time, EPA has also been able to incorporate a few additional provisions into its models, such as energy efficiency standards. EPA has not yet been able to adequately incorporate other standards within the modeling framework such as those that apply to the transportation or electricity sectors (e.g., fuel economy or performance standards). Likewise, while formal modeling can shed light on the key aspects of the cap-and-trade policy, it cannot replicate every aspect of private decision-making and therefore will not capture the impact of certain details. For this reason, modeling results are instructive in highlighting the magnitude and direction of impacts and the way they may change under different conditions but should not be interpreted as precise estimates of what will occur once a policy has been implemented.

The paper is organized as follows. First, it evaluates key elements of the two bills that, in most cases, are informed by EPA modeling analyses: cap levels and coverage, offset limits and sources, banking and borrowing, reserve allowances, energy efficiency provisions, incentives for CCS, energy-intensive and trade-exposed output-based rebates, transportation provisions, and allocations. For each of these topics, the paper describes the purpose of the provision and how the bills differ, then assesses how these differences would be expected to impact allowance prices and costs. Second, the paper summarizes the economic impacts of H.R. 2454 and S. 1733. Third, it discusses the importance of modeling assumptions, particularly with regard to technology and international action. Fourth, distributional and temperature impacts are discussed. Finally, the appendix describes the recent EPA modeling analyses that inform this paper.

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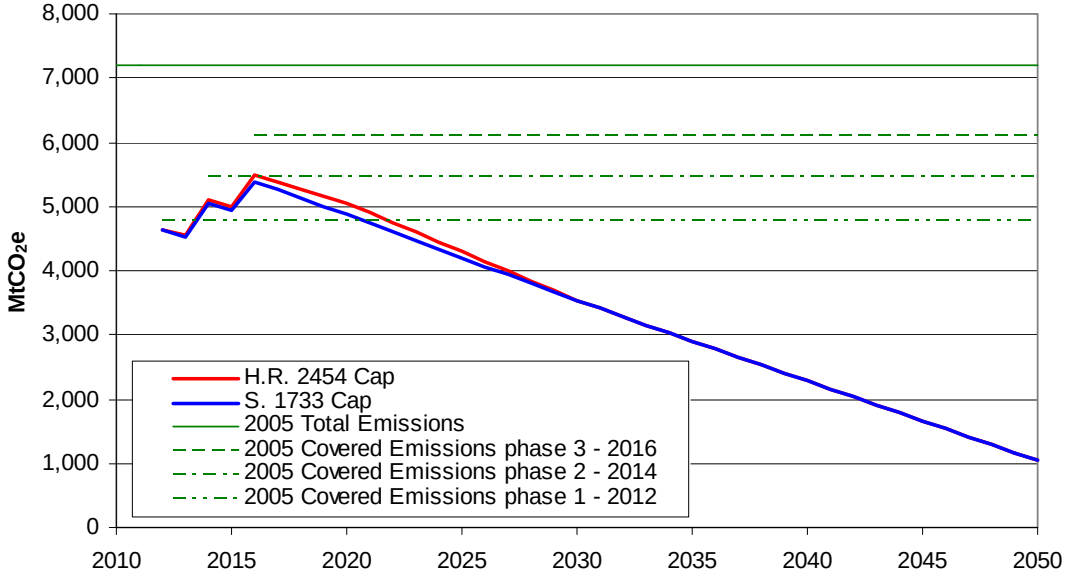
**Cap Levels and Coverage**

Both H.R. 2454 and S. 1733 place caps on the overall amount of greenhouse gas emissions allowed from all covered entities by establishing a separate quantity of emissions allowances for each year. In addition to establishing a cap, H.R. 2454 and S. 1733 allow covered sources to trade allowances. The requirement that a covered entity hold an allowance for every ton of greenhouse gas emissions it emits creates scarcity in the market for allowances, which in turn implies a positive price in the market. The cap-and-trade policy does not mandate how sources achieve this goal. Absent other legislated requirements, a source can choose the cheapest method of compliance, by reducing its output, changing its input mix, modifying the underlying technology used in production, or purchasing allowances or offsets from other entities with lower abatement costs. This assures that the cap is met at the cheapest possible cost to covered sources while inducing long-term innovation and change in the production and consumption of energy-intensive goods in related markets. The cap-and-trade policy often is carefully crafted to afford sources numerous flexibilities that further decrease the costs of compliance, such as the option to purchase offsets from non-covered sources; the ability to bank or borrow allowances across time periods; and the ability to purchase allowances from the government if the price reaches a particular threshold. Standards that impose restrictions on the way in which a particular subset of sources meet the cap will reduce this flexibility and, if binding, likely increase the costs without delivering additional emission reductions. However, it is difficult to model the effects of such standards on the behavior of sources and to reflect the costs they may impose.

Both H.R. 2454 and S. 1733 set the cap level in 2012, 2030, and 2050 to reduce emissions from covered sources by 3%, 42%, and 83% from 2005 levels respectively. However, compared to HR. 2454, S. 1733 changes the 2020 cap level from 17% to 20% below 2005 emissions levels from covered sources. It should be noted that the caps specified in S. 1733 are equivalent to the caps first specified in the Waxman-Markey discussion draft, which was also analyzed by EPA (EPA 2009a). This change in the 2020 cap level decreases the cumulative number of allowances available between 2012 and 2050 by one percent from 132.2 gigatons carbon dioxide equivalent ($GtCO_2e$) to 130.6 $GtCO_2e$. Figure 1 illustrates the nearly imperceptible difference, which is indicated by the gap between the lines representing the two cap levels over time. Because covered entities are allowed to bank, and to a limited extent, borrow emissions allowances, it is the cumulative number of allowances over the entire 2012 – 2050 time frame that drives allowances prices. All else being equal, this tightening of the cap will raise allowance prices on the order of one percent in all years from the allowance price in the core scenario of EPA's H.R. 2454 analysis ($13/$tCO_2e$ 2015; $16/$tCO_2e$ in 2020). Similar changes would be seen in the cost of the bill for the average household. The changed caps will also likely result in slightly greater usage of domestic and international offsets, all else being equal.

*Figure 1 – S. 1733 and H.R. 2454 Cap Levels*




The coverage in S. 1733 is unchanged from H.R. 2454. Both bills contain three separate phases each covering a greater percentage of emissions. In phase 1, from 2012 – 2013, covers 66.2% of year 2005 greenhouse gas emissions as measured in the Inventory of US Greenhouse Gas Emissions and Sinks (EPA 2008c). In phase 2, from 2014 – 2015, 75.7% of year 2005 greenhouse gas emissions are covered. In phase 3, 2016 and after, 86.4% of year 2005 greenhouse gas emissions are covered.[2]

**Offset Limits and Sources**

H.R. 2454 and S. 1733 both establish offsets credits as an additional method for entities to comply with the requirement to hold an emissions allowance for each ton of greenhouse gas emissions. Instead of purchasing an emissions allowance for each ton of emissions, entities may also demonstrate compliance by purchasing an offset credit that represents reductions in greenhouse gas emissions (or increased sequestration of greenhouse gases) from a non-covered source (e.g., reduced emissions from landfill $CH_4$, increased $CO_2$ sequestration from changed agricultural tillage practices, or increased $CO_2$

[2] Major sources covered in phase 1 include: $CO_2$ from electric power generators; $CO_2$ from non-industrial petroleum use; some $CO_2$ from industrial usage of petroleum; $CO_2$ from the non-energy use of fuels; $N_2O$ from product uses; PFC from semiconductor manufacturing; and $SF_6$ from electrical transmission and distribution, magnesium production and processing, and semiconductor manufacturing. Major sources covered in phase 2 include: $CO_2$ from industrial usage of coal; remaining $CO_2$ from industrial usage of petroleum; most $CO_2$ from the industrial usage of natural gas; $CO_2$ from iron and steel production; $CO_2$ from cement manufacturing; $CO_2$ and $N_2O$ from fertilizer production. Sources covered in phase 3 include: $CO_2$ from residential, transportation, and commercial usage of natural gas; remaining $CO_2$ from industrial usage of natural gas. See the data annex to EPA's analysis of H.R. 2454 (EPA 2009b) for a spreadsheet detailing covered sources.



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sequestration from afforestation). The non-covered sources providing offset credits can either be domestic or international.

*Table 1: Summary of Key Offset Provisions*

| | **H.R. 2454** | **S. 1733** |
|---|---|---|
| Overall Offset Limits | 2 billion tons | 2 billion tons |
| Source Level Offset Limits | Does not aggregate to the overall limit | Aggregates to the overall limit |
| Domestic & International Offset Limits | International: 1 billion tons<br>Domestic: 1 billion tons | International: 0.5 billion tons<br>Domestic: 1.5 billion tons |
| Criteria for Adjusting International Offset Limit | Domestic offset usage below 0.9 billion tons | Domestic offset usage below 0.9 billion tons |
| Revised International Offset Limit | 1.5 billion tons | 1.25 billion tons |
| Performance standards | Landfill and coal mine $CH_4$ covered by performance Standards, reducing there ability to supply offsets. | Landfill and coal mine $CH_4$ are not covered by performance standards. |

*Offsets Limits*

Both H.R. 2454 and S. 1733 limit annual offset usage to 2 billion tons,[3] and then specify how the overall offset limit should be calculated on a per covered source basis to generate source level limits on the use of offsets.[4] The formula for establishing the source level offset limit in H.R. 2454 does not add up to the overall 2 billion ton limit.[5] S. 1733 corrects this problem so the source level limit is now consistent with the overall 2 billion

[3] H.R. 2454 sec. 722 (d)(1)(A) and S. 1733 sec. 722 (d)(1)(A).
[4] H.R. 2454 sec. 722 (d)(1)(B) and S. 1733 sec. 722 (d)(1)(B).
[5] H.R. 2454 Sec 722 (d) (1) (A) allows covered entities to satisfy a specified percentage of the number of allowances required to be held for compliance with offsets credits. H.R. 2454 Sec 722 (d) (1) (B) states that for each year, the specified percentage is calculated by dividing two billion by the sum of two billion and the annual tonnage limit for that year. For example, in 2012, when the cap level is 4.627 GtCO2e, the percentage would be 30.20%; and in 2050, when the cap level is 1.035 GtCO2e the percentage would be 65.90%. The number of allowances required to be held for compliance is equal to the amount of covered emissions, so for any given firm the amount of offsets they are allowed to use is equal to the product of their covered emissions and the percentage specified above. The total amount of offsets allowed is equal to the product of the total amount of covered emissions and the specified percentage. In order for this to be equal to the 2 billion ton limit on offsets specified above, total covered GHG emissions would have to be equal to the cap level plus 2 billion tons. There are several reasons why this is unlikely to be the case. First, even if covered emissions remain at reference levels, in the early years of the policy they will not be 2 billion tons over the cap level. Second, if firms bank allowances, their covered GHG emissions will be reduced, which will reduce the amount of offsets they are allowed to use. Third, in the later years when firms are drawing down their bank of allowances, it is possible for covered GHG emissions to be more than 2 billion tons above the cap, which means that the pro rata sharing formula can be in conflict with the overall 2 GtCO2e limit on offsets usage.



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ton limit on offset usage.[6] For the purposes of economic analysis or modeling, this change is not likely to have any impact on allowance prices, as the limits on offset usage were not binding in EPA's analysis of H.R. 2454, and the revised limits in S. 1733 would also not be constraining.

In addition to the overall limits placed on the amount of offsets a covered entity can use, both H.R. 2454 and S. 1733 place limits on the amount of offsets that can come from either international or domestic sources. H.R. 2454 states that not more than one-half of offsets can come from domestic offset credits and not more than one-half can come from international offset credits. S. 1733 differs from H.R. 2454 in that not more than three-quarters of offsets can come from domestic offset credits and not more than one-quarter can come from international offset credits.[7]

After placing limits on domestic and international offset usage, both H.R. 2454 and S. 1733 state conditions under which those limits are modified. In both bills, if the estimated usage of domestic offsets is expected to be below 0.9 billion tons in any year, the limits on international offsets usage are modified. When this condition is met, H.R. 2454 allows additional international offset credits equal to the difference between 1 billion tons and the amount 1 billion tons exceeds the estimated domestic offset usage, up to an additional 0.5 billion tons of international offset credits. This has the potential to increase the limit on international offset credits in H.R. 2454 to 1.5 billion tons per year. In contrast, when this condition is met, S. 1733 allows additional international offset credits equal to the difference between 1.5 billion tons and the amount 1.5 billion tons exceeds the estimated domestic offset usage, up to an additional 0.75 billion tons of international offset credits. This can potentially increase the limit on international offset credits in S. 1733 to 1.25 billion tons per year, 0.25 billion tons less than in H.R. 2454.[8]

In EPA's analysis of H.R. 2454, estimated usage of domestic and international offsets are below the limits established in H.R. 2454, and below the limits established in S. 1733 in all scenarios that do not place constraints on technology. Thus the changed language on offsets limits will not impact the costs of the bill as estimated by EPA in scenarios that do not place limits on technology. However, in scenarios with limits on the availability of technologies such as nuclear, biomass, and CCS, the limits on international offset usage would be reached. In these scenarios, when the limit on domestic offsets is not met, H.R. 2454 adjusts the limit on international offset usage to allow approximately 1.5 $GtCO_2e$ per year, while S. 1733 adjusts the limit on international offset usage to allow 1.25 $GtCO_2e$ per year. The fewer international offsets allowed by S. 1733 compared to H.R. 2454 in these limited technology scenarios would require an extra 9.5 $GtCO_2e$ of abatement from covered sources cumulatively over the 2012 – 2050 time frame, and would result in higher allowance prices.

[6] S. 1733 sec. 722 (d)(1)(B) establishes the entity level limit on offsets as the product of 2 billion tons and that entity's share of covered emissions from the previous year.
[7] H.R. 2454 sec. 722 (d)(1)(B) and S. 1733 sec. 722 (d)(1)(B).
[8] H.R. 2454 sec. 722 (d)(1)(C) and S. 1733 sec. 722 (d)(1)(C).



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*Coal Mine and Landfill $CH_4$: Offsets or Performance Standards*

An additional difference between the two bills is that H.R. 2454 requires the establishment of performance standards for uncapped stationary sources including: any individual sources with uncapped emissions greater than 10,000 tons $CO_2$e; and any source category responsible for at least 20% of uncapped stationary GHG emissions. The bill requires that source categories to be identified by EPA include those responsible for at least 10% of uncapped methane emissions. Performance standards for new sources would then be set under the provisions of section 111 of the Clean Air Act. In general, performance standards are emissions limits set based on an analysis of best demonstrated technologies but do not require that particular technologies be used. Under section 111(d), states are then directed to set performance standards for existing sources based on the new source performance standards and may take into account other criteria such as a facility's remaining useful life. Sources that would potentially be covered by this provision likely includes, at a minimum: landfills; coal mines; and natural gas systems. Including these sources under performance standard provisions eliminates their eligibility to provide offset credits.

In S. 1733, these performance standard provisions are no longer included, and landfill, coal mine, and natural gas system methane are instead eligible to provide offset credits.[9] An extension of EPA's analysis of H.R. 2454 has shown that allowing these sources as offset projects under H.R. 2454 instead of covering them under performance standards would decrease allowance prices by 2% in all years from the allowance price in the core scenario of EPA's H.R. 2454 analysis ($13/t$CO_2$e 2015; $16/t$CO_2$e in 2020); increase 2012 – 2050 cumulative domestic offsets usage by 46% (6 Gt$CO_2$e); decrease 2012 – 2050 cumulative international offset usage by 12% (5 Gt$CO_2$e); and increase 2012 – 2050 cumulative U.S. GHG emissions by 6 Gt$CO_2$e (Fawcett, 2009). The overall impact on the modeled cost of the policy would likely be small.

However, there are other general equilibrium consequences from the way that these emission sources are controlled that are not included in the reduced form modeling used to generate these results. Including these sources in an offsets program allows the market to determine the appropriate level of abatement from these sources so that the marginal cost of abatement is equal to the offset price. A performance standard dictates what level of abatement particular sources must achieve. If costs end up being lower than expected, then there will be less abatement activity than under an offsets program, although sources may be able to over-comply and generate additional offsets; if costs end up being higher than expected, there will be more abatement activity than under an offsets program, and the marginal cost of abatement for these sources will be higher than for sources covered by the cap.

[9] Note that S. 1733 gives the EPA Administrator discretion to set performance standards for uncapped sources after 2020, which could affect the availability of offsets from these sectors. Previous EPA modeling of climate legislation has generally assumed that such discretionary options are not exercised.



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*Domestic Agriculture and Forestry Offset Provisions*

The domestic offset provisions in S.1733 are unchanged from H.R. 2454 in regard to their treatment of agriculture and forestry offsets. EPA's analysis uses the FASOM model because it is the only agricultural sector model that supports a comprehensive analysis of dynamic physical and economic responses to carbon policy. FASOM includes three important feedback effects: potential revenue from sale of offsets, producer response to changing input costs, and consumer demand responsiveness. FASOM features a broad range of offset-generating activities. Specifically, EPA estimates that 100 million metric tons of carbon could be sequestered by 2040 in agricultural soils alone. Overall, agricultural producer's surplus increases by 14% (in annuity terms) over the full period of analysis.

EPA's analysis of H.R. 2454 is intended to provide an estimate of domestic offset supply; it is not meant to prejudge what sources would be eligible for offsets. Several independent and follow-on studies have been recently undertaken to provide more detailed domestic agricultural and forestry results. In addition, the FASOM model has been updated over the summer (Baker *et al.*, forthcoming). Baker *et al.* (forthcoming) use the updated FASOM model, and their results show roughly twice as much carbon offset potential in agriculture compared to the March 2009 FASOM analysis on which EPA based its analysis of H.R. 2454, though the authors have not attempted to model specific eligibility or administrative issues. Baker *et al.* analyze results for crop and livestock producers across ten regions under three pricing levels, for a total of 120 combinations, and find all but 6 combinations yield net income increases. Summing the impacts to producers, processors, and consumers, the U.S. agriculture sector receives net annualized benefits of $1.2 billion - $18.8 billion. We expect that incorporating the updated FASOM results would result in greater domestic offset use yet remain below the revised limits on domestic offset use in both H.R. 2454 and S.1733.

*International Offset Supply Estimates*

EPA's analysis of H.R. 2454 used marginal abatement cost curves representing international abatement opportunities. The international non-$CO_2$ and terrestrial sinks abatement schedules were generated by first making assumptions about when developed and developing countries adopt climate policy; second, for each mitigation option a determination was made, dependent on whether or not the source country was assumed to have adopted binding caps, regarding potential eligibility for a future U.S. mitigation program, or in some cases applying a uniform adjustment;[10] third, separate offset mitigation cost schedules were constructed with eligible or adjusted options for developed and developing countries. International energy-related $CO_2$ abatement schedules were developed using the MiniCAM model. Specifically, the model was run using the reference case developed for the U.S. Climate Change Science Program Synthesis and Assessment Product 2.1a ("CCSP SAP 2.1a," US CCSP, 2006). International forestry related mitigation schedules were generated using the Global Timber Model.

[10] This determination of eligibility was not determined for methane from the natural gas and oil sectors, so uniform adjustments were applied.



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In addition to generating the supply curve for international abatement, it is necessary to determine what the competing demand is for international abatement. This will determine how many international offsets are available for U.S. sources to purchase. Determining demand requires assumptions about the reference case emissions of developed and developing countries, and assumptions about the climate policies adopted by other countries. Greater reference case emissions growth, or tighter caps on emissions in other countries, increases international demand for abatement, and thus will drive up the price of international offsets, resulting in less U.S. reliance on them, all else being equal. This may result in greater use of domestic offsets. See the '*international actions'* section below that discusses how differing assumptions about international actions impact the results of the HR 2454 analysis. Also see the '*sensitivities on offset availability'* section below for a discussion of how differing assumptions about the availability of offsets, particularly international offsets, impact the estimated costs of climate policy.

**Banking and Borrowing**

Both H.R. 2454 and S. 1733 allow for unlimited banking of allowances, and some limited borrowing of allowances. Banking allowances allows covered entities to over-comply in the early years of the program so that covered greenhouse gas emissions, accounting for offsets, are below the cap. In the later, years the bank of allowances that has been built up can be drawn down so that covered greenhouse gas emissions, again accounting for offsets, are above the cap. While the cap is not met exactly in any given year, over time cumulative covered greenhouse gas emissions are equal to the cumulative cap.

Because of the option to bank allowances, the rate of return for holding allowances is expected to equalize with the rate of return from other available investments. For modeling purposes, this means that the allowance price will grow at an exogenously set interest rate. If instead the allowance price were rising faster than the interest rate, firms would have an incentive to increase abatement in order to hold onto their allowances, which would be earning a return better than the market interest rate. This would have the effect of increasing allowance prices in the present, and decreasing allowance prices in the future. Conversely, if the allowance price were rising slower than the interest rate, firms would have an incentive to draw down their bank of allowances, and use the money that would have been spent on abatement for alternative investments that earn the market rate of return. This behavior would decrease prices in the present and increase prices in the future. Because of these arbitrage opportunities, the allowance price is expected to rise at the interest rate.

In EPA's analyses a 5% interest rate is used for banking. For comparison, in the five models that participated in the Energy Modeling Forum 22 U.S. transition scenarios study,[11] the interest rate used for banking ranged from 4 to 5 percent (Fawcett, *et al*.,

[11] The Applied Dynamic Analysis of the Global Economy model (ADAGE) from the Research Triangle Institute; the Emissions Predictions and Policy Analysis model (EPPA) from the Massachusetts Institute of Technology; the Model for Emissions Reductions in the Global Environment (MERGE), from the Electric



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forthcoming). In EIA's analyses of H.R. 2454 and other climate bills, the NEMS model uses a 7.4 percent interest rate for banking reflecting the average cost of capital in the electric power sector (EIA 2009). CBO's analyses of H.R. 2454 uses 5.6 percent as the interest rate for banking reflecting the after-tax long-run inflation-adjusted rate of return to capital in the U.S. nonfinancial corporate sector (CBO 2009). Thus, all else being equal, models that use a lower interest rate for banking show greater amount of banking, higher allowance prices in the early years as the bank is growing, and lower allowance prices in the later years as the bank is being drawn down.

**Strategic Reserve / Market Stability Reserve**

Both H.R. 2454 and S. 1733 set aside a portion of allowances to establish a reserve pool of allowances that are made available at auction if allowance prices rise high enough. Auction revenues from selling these reserve allowances can then be used to purchase offsets that are used to refill the reserve. These provisions are designed to contain price volatility, control costs, or both, depending on the specifics of the provisions. EPA has not assessed their ability to accomplish these stated goals. However, we do discuss the key differences between how these reserves are designed in H.R. 2454 and S. 1733 below.

The market stability reserve established in S. 1733 differs in important ways from the strategic reserve described in H.R. 2454. A key difference is that a greater number of allowances are taken out of the cap and placed in the reserve under S. 1733, as indicated in the table 2 below.

*Table 2: Strategic / Market Stability Reserve Allocations*

| | **HR. 2454** | **S. 1733** |
|---|---|---|
| **2012 – 2019** | 1% | 2% |
| **2020 – 2029** | 2% | 3% |
| **2030 – 2050** | 3% | 3% |

Cumulatively over 2012 – 2050, H.R. 2454 places 2.7 billion allowances in the strategic reserve, representing 2.1% of total allowances, while S. 1733 places 3.5 billion allowances in the market stability reserve representing 2.7% of total allowances. If allowance prices remain low and the minimum prices for releasing allowances from the reserves are not met, then the existence of the reserve has the effect of tightening the cap (see figure 2 below) and raising allowance prices.

While EPA did not model the strategic reserve mechanism in its analysis of H.R 2454, subsequent modeling has shown that including the reserve would increase allowance prices by approximately 1% in all years from the allowance price in the core scenario of

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Power Research Institute; MiniCAM, from the Pacific Northwest National Laboratory / Joint Global Change Research Institute; the Multi-Region National Model - North American Electricity and Environment Model (MRN-NEEM), from Charles River Associates; and the Intertemporal General Equilibrium Model (IGEM), from Dale Jorgenson Associates



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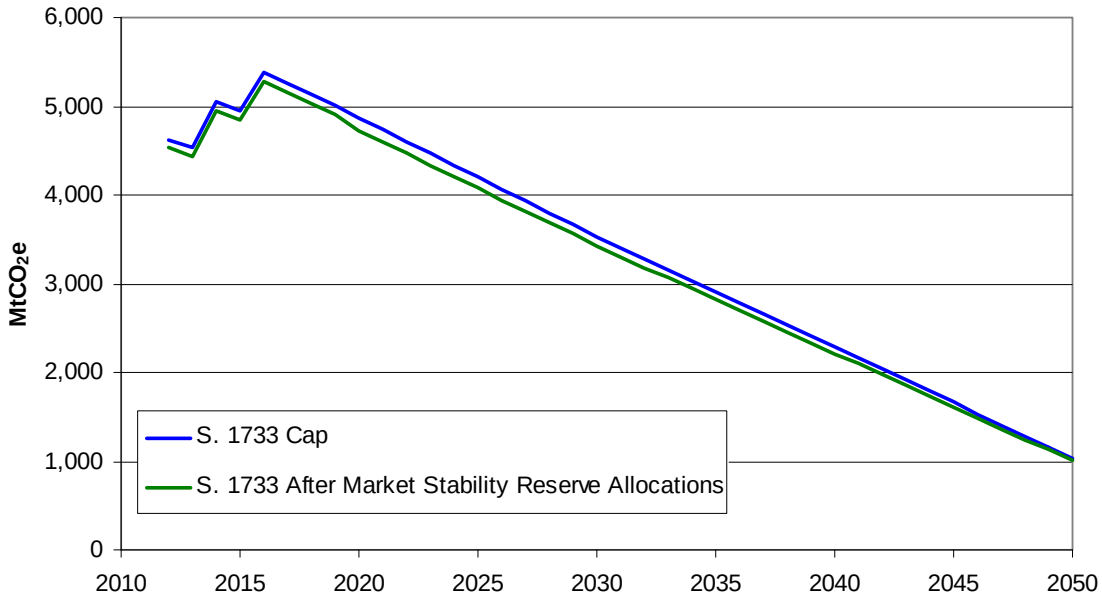
EPA's H.R. 2454 analysis ($13/t$CO_2$e 2015; $16/t$CO_2$e in 2020), and also increase the usage of international offsets. Because S. 1733 places a greater percentage of allowances in the reserve, it would result in a slightly larger increase in allowance prices in a scenario where allowance prices remain low enough that the reserve allowances are not purchased. For context, the change in the 2020 cap from 17% (H.R. 2454) to 20% (S. 1733 and Waxman Markey discussion draft) below 2005 levels reduces the cumulative number of allowances by 1.6 billion tons, and increases allowance prices by approximately one percent. The change in the allocation to the reserve in S. 1733 compared to H.R. 2454 reserves an additional 0.8 billion tons, and thus should have a smaller impact on allowance prices.

*Figure 2 – S. 1733 Cap Levels with and without Market Stability Reserve*




Another major change is how the minimum reserve price is set. H.R. 2454 sets the minimum reserve price at $28 (in constant 2009 dollars) in 2012, and the price rises at a real rate of 5 percent through 2014. Starting in 2015, the minimum reserve price is set at 60 percent above the 36-month rolling average of that year's emissions allowance vintage. This way of setting the minimum reserve price allows the reserve to be triggered when price volatility leads to suddenly high prices; however, sustained non-volatile high allowance prices would not trigger the reserve. The strategic reserve in H.R. 2454 is primarily designed to address price volatility and not cost containment in general. This approach does not provide meaningful price certainty to inform business planning.

In contrast, S. 1733 sets the minimum reserve price at $28 (in constant 2005 dollars) in 2012 rising at a real rate of 5 percent through 2017, then rising at a real rate of 7 percent thereafter. This change results in a predetermined minimum reserve price for every year, which can be met either by high allowance prices caused by price volatility, or by sustained non-volatile allowance prices. The market stability reserve in S. 1733 is designed to address both price volatility and cost containment in general. This approach

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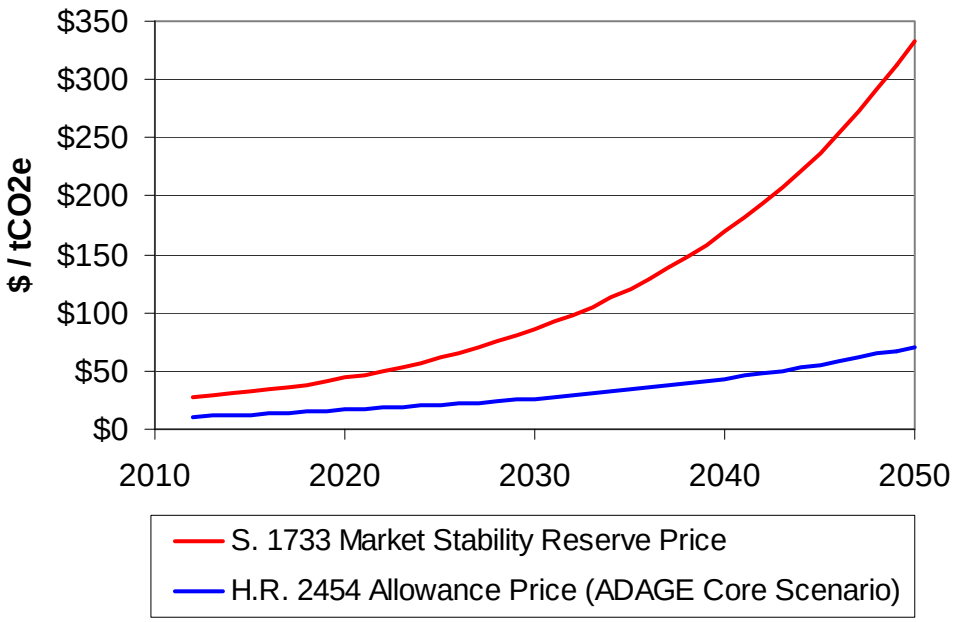
provides better price certainty, although the price ceiling is not binding, depending on the outcome of the reserve auctions. Figure 3 below shows the minimum reserve price for S. 1733 with the estimated allowance price from H.R. 2454 for comparison. Note that the figure does not depict the minimum reserve price for H.R. 2454, as that price will vary depending on the realized allowance price.

*Figure 3 – S. 1733 Market Stability Reserve*




S. 1733 places limits on the number of reserve allowances that may be auctioned in each year. The limits are equal to 15% of the cap from 2012 – 2016 and 25% of the cap thereafter. These limits allow for the initial allowances placed in the reserve to be used very quickly. For example, if the minimum reserve price was reached immediately in 2012, and allowances were sold from the reserve up to the limit, then all of the 3.5 billion allowances initially placed in the reserve would be used by 2016.

If allowance prices are above the minimum reserve price, then the ability of the reserve to contain prices depends on the ability of the government to refill the reserve. If only the allowances initially placed in the reserve are auctioned, then the reserve will simply make allowances that were allocated to the reserve in later years available instead in early years, without any impact on the cumulative number of allowances available. This will have no impact on modeled allowance prices. If the reserve can be refilled, then auctioning these refilled reserve allowances would increase the amount of greenhouse gas emissions a covered entity could emit compared to a scenario with no reserve in the first place, and thus have the potential to reduce allowance prices.

S. 1733 allows reserve auction revenues to be used to purchase domestic and international offset credits that would be retired to create additional allowances to be

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auctioned under the market stability reserve. If offset credits are available for a price lower than the minimum reserve price, then they can be purchased to refill the reserve and help contain allowance prices. This situation would primarily be expected to hold when the limits placed on domestic or international offset usage are binding so that the market clearing offset price is lower than the allowance price. However, EPA's modeling has shown that the scenarios with the highest allowance prices generally have limits on the availability of technology and the availability of offsets. If offsets are not available for purchase through the offset market, resulting in high allowance prices, it is likely that they would also not be available to refill the market stability reserve. This, in turn, implies a limited ability of the strategic reserve to protect against sustained higher allowance prices when offset availability is limited.

**Energy Efficiency Provisions**

In EPA's analysis of H.R. 2454, three areas of energy efficiency provisions were addressed: building codes, energy efficiency-related allowance allocations, and the energy savings component of the Combined Efficiency and Renewable Electricity Standard (CERES). For modeling purposes, we assumed that one quarter of the CERES requirement would be met through electricity savings.[12] EPA did not model several other sections of the energy efficiency provisions, including lighting and appliance standards, smart grid advancement, industrial energy efficiency programs, and improvements in energy savings performance contracting.[13] It is also worth noting that in EPA's analysis of H.R. 2454 the energy savings and associated costs of the energy efficiency provisions are estimated outside of ADAGE and imposed exogenously into our policy scenarios. Thus, certain interactions may not be fully accounted for in EPA's analysis. Specifically, some overlap may exist between the estimate of impacts driven by the energy efficiency provisions and the price response-driven energy efficiency investments reflected within ADAGE.

Like H.R. 2454, S. 1733 includes a building codes provision and energy efficiency-related allowance allocations. However it does not include any provision comparable to the CERES of H.R. 2454. Unlike H.R. 2454, the building codes provision in S. 1733 does not specify target levels of reductions in energy use, federal authority to implement, or federal ability to withhold allowance allocations for non-compliance. Instead, the provision directs EPA, or another designated agency, to establish targets through rulemaking and does not provide for federal implementation or withholding of allowance allocations. The energy efficiency-

[12] The CERES requires retail electric suppliers to meet a growing percentage of their load with electricity generated from renewable resources and electricity savings. It begins at 6% in 2012 and gradually rises to 20% in 2020. One quarter of the requirement may be met through electricity savings. Upon petition by a state's governor up to 40% of the requirement may be met through electricity savings.

[13] Building codes are in Sec. 201; energy efficiency-related allowance allocations are specified in Sec. 321; and the Combined Efficiency and Renewable Electricity Standard (CERES) is specified in Sec. 101 of H.R. 2454. Lighting and appliance standards are in Sec. 211-219; smart grid advancement is in Sec. 141-146; industrial energy efficiency programs are in Sec. 241-245; and improvements in energy savings performance contracting are specified in Sec. 251.



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related allowance allocations in S. 1733 (specified to EPA by Senate Environment and Public Works Committee Staff) are very similar to those in H.R. 2454 except for the impact of the increase in allowances taken off-the-top for the strategic reserve and deficit neutrality. This effect reduces the energy efficiency-related allowance allocations by approximately 11% through 2029, 22% from 2030-2039, and 25% thereafter. The percentage allocations (before accounting for the impact of the off-the-top allocations) to natural gas, and home heating oil and propane consumers, as well as the minimum proportions that are required to be used for energy efficiency, are identical to those in H.R. 2454. Similarly, the allocations to state and local investment in energy efficiency and renewable energy and associated restrictions on uses are similar to those in H.R. 2454 on a percentage basis before accounting for the off-the-top allocations.

In total, because there is no provision comparable to the CERES in H.R. 2454, the building codes provision does not specify target energy use reduction levels or provide federal authorities to ensure compliance, and the energy efficiency-related allowance allocations are lower, EPA expects the impacts (e.g., changes in energy demand and prices) of energy efficiency provisions in S. 1733 to be approximately half those estimated in our analysis of H.R. 2454 . Specifically, the effects of these three areas of energy efficiency provisions are included in EPA's core policy scenario of H.R. 2454 and the combined effects of these provisions are highlighted through the "without energy efficiency provisions" scenario that removes them from the core policy scenario. The resulting modeled economic impacts of the energy efficiency provisions include modest reductions in allowance prices (~1.5%), fossil fuel prices (coal and natural gas ~1%), and electricity prices (<1%) from 2015-2050.[14]

**Incentives for CCS**

Both H.R. 2454 and S. 1733 contain considerable financial incentives for carbon capture and storage (CCS) on new and existing facilities, as shown in table 3 below. The proposals each contain about $10 billion ($1 billion per year over ten years) for demonstration and early deployment of the technology in addition to bonus allowances that are awarded to early projects based upon the amount of $CO_2$ that is captured and sequestered. The early deployment funding is raised from fees on electricity sales. The bonus allowance pool under H.R. 2454 can award up to 5.32 billion allowances over the life of the program and 4.19 billion allowances under S. 1733. Fewer bonus allowances are available under S. 1733 due to that bill's more stringent 2020 cap, its allocation of a larger share of overall allowances to the market stability reserve, and its use of a larger share of overall allowances for deficit reduction. However, that difference does not necessarily translate to an equivalent difference between the bills in the aggregate monetary support for CCS or the effect on overall CCS deployment, for reasons described below.

[14] Note that the only analysis of the impact of the CERES on driving increased renewable electricity generation was conducted as a side case to the electricity sector modeling and not modeled within the core ADAGE policy case.



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The CCS bonus is a monetary incentive for each ton of $CO_2$ sequestered, given in the form of allowances from the (limited) bonus pool. Thus, the number of allowances granted per ton of $CO_2$ sequestered is a function of the allowance price and the bill's per-ton monetary incentive. Under both H.R. 2454 and S. 1733, a pre-determined fixed per-ton value is given for the earliest projects up to a certain capacity threshold (referred to as a "tranche"). Subsequent projects must participate in a reverse auction approach where participants' bids help to determine the appropriate per-ton value that maximizes CCS deployment until the bonus allowance pool runs out. The per-ton value structure of the bonus in S. 1733 differs from H.R. 2454 whereby fixed per-ton values remain in effect for a larger share of initial CCS capacity (until 20 GW of capacity is built under S. 1733 versus 6 GW in H.R. 2454).

*Table 3: Incentives for CCS*

| | **H.R. 2454** | **S. 1733** |
|---|---|---|
| **Early Deployment** | $1 billion annually for 10 years | $1 billion annually for 10 years |
| **Total Bonus Pool** | 5.32 Billion | 4.19 Billion |
| **1st Tranche**[15] | $90/ton for first 6 GW + $10/ton built before 2017 | $96/ton for first 10 GW + $10/ton built before 2017 |
| **2nd Tranche** | Reverse Auction | $85/ton for next 10 GW |
| **3rd Tranche** | N/A | Reverse Auction |

Note: bonus amount is for 90% capture. Lesser capture rates receive smaller bonus values.

It is possible that with a larger tranche of initial projects eligible for a fixed per-ton value incentive, S. 1733 may accelerate the deployment of CCS.[16] However, if the fixed per-ton values are higher than the market would accept to make all of those initial projects economic, the pool of bonus allowances will be exhausted earlier and will result in less total CCS purely arising from the bonus incentive. There are other factors that may act to increase CCS deployment under S. 1733, such as higher allowance prices and higher demand for electricity. In addition, by accelerating the early deployment of CCS technology, there could be some learning-by-doing that assists with accelerating the commercial viability of CCS.

[15] S. 1733 made changes to the definition of capacity that determines the thresholds for each tranche to apply to the "treated generating capacity" (Sec. 786) instead of the total capacity of the eligible generating unit under H.R. 2454. This would have no effect on EPA modeling.

[16] This approach is most likely intended to address risk rather than cost minimization and/or optimization, and so it may not be reflected in EPA modeling.



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**Energy Intensive / Trade Exposed Output Based Rebate Provisions**

Both H.R. 2454 and S. 1733 establish output based rebates of allowances for covered entities that are both energy intensive and trade exposed (EI/TE). S. 1733 establishes rebates for EI/TE sectors, equal to the product of firm output, an industry average emissions factor, and the allowance price The eligibility criteria, language describing the rebate calculation, and phase-out schedule are mostly unchanged from H.R. 2454. The changes that have been made include changing the base year for the calculation of industry average emissions factors, and adding additional details about the way averages are calculated. The ADAGE model aggregates energy intensive manufacturing sectors in such a way that it masks the distinctions that might be supported by this language. The changed language would not affect the modeled costs of the bill or the modeled impacts on EI/TE sectors.

The EI/TE sectors would be affected by other provisions of S. 1733 that impact allowance prices. An analysis of the impacts of the EI/TE provisions under S. 1733 would be somewhat different than the analysis under H.R. 2454 because of the different cap and other changes that would affect allowance market conditions (e.g., larger amounts of allowances allocated off-the-top to the strategic reserve and deficit neutrality, and the alternative assumptions about international actions discussed below). These changes would likely have a relatively small impact on allowance prices and the overall costs of the policy.

**Allocations**

The initially released version of S. 1733 did not include information on the percentage of allowances allocated to or auctioned for various purposes. However, Senate Environmental and Public Works Committee staff have provided details on the allocation and auction percentages to EPA, and these details are expected to be included in the version of S. 1733 that will be introduced in committee. Some of the changes to allocations that impact specific provisions (e.g., energy efficiency allocations and reserve allowance allocations) are discussed above along with the likely impact the change will have on costs. One important change to note is that S. 1733 devotes a much greater portion of allowance to deficit reduction. S. 1733 auctions 10 percent of allowances for the purpose of deficit reduction from 2012 – 2029, 22% from 2030 – 2039, and 25% from 2040 – 2050. For comparison H.R. 2454 auctioned 13% of current vintage allowance for deficit reduction in 2012 and 2013 and approximately 1% from 2014 – 2025; in addition, from 2014 to 2020 it auctioned a number of future vintage allowances equal to 10% to 14% of cap levels. H.R. 2454 did not auction allowances for deficit reduction after 2025. However, EPA has a limited ability to evaluate the impact of such changes on modeled costs across proposals unless the changes result in behavioral change. This is because the models used by EPA are calibrated to deficit neutrality. As such, S. 1733 will bring the

modeled costs of the policy closer to the truer measure of overall costs. Estimates of allowance prices and household costs will not be significantly affected by this change.

**Summary of Economic Impacts**

This paper has presented an assessment of how individual differences between S. 1733 and H.R. 2454 are expected to influence the costs of the bill. These assessments have drawn upon existing modeling by EPA that used the full computable general equilibrium models (ADAGE and IGEM), as well as modeling that used reduced form versions of EPA's models, and have focused on the effect the differences have on allowance prices and costs. It is likely that the full suite of EPA models would show that the impacts of S. 1733 would be similar to those that were estimated for H.R. 2454. We therefore summarize the main results from our analysis of H.R. 2454 in table 4 below.

*Table 4: Summary of Economic Impacts of H.R. 2454*[17]

| | | 2015 | 2020 | 2030 | 2050 |
|---|---|---|---|---|---|
| Allowance Price ($/t$CO_2$e) | Core scenario | $13 | $16 | $26-$27 | $69-$70 |
| | Range across all scenarios | $13-$24 | $16-$30 | $26-$49 | $69-$130 |
| Undiscounted household consumption loss, relative to no policy case, core scenario | Percent | 0.03%-0.08% | 0.10-0.11% | 0.31-0.30% | 0.76-0.78% |
| | Dollars per day | $0.06-$0.19 | $0.23-$0.29 | $0.76-$1.00 | $2.50-$3.52 |
| Percentage increase in household consumption increase from 2010 | No policy case | 8-10% | 15-19% | 31-41% | 71-96% |
| | Core scenario | 8-10% | 15-19% | 31-40% | 69-94% |
| Electricity price increase, relative to no policy case | Percent | unchanged | unchanged | 13% | 35% |
| Household energy expenditure increase, relative to no policy case | Percent increase (decrease) | (2%) | (7%) | 2% | 21% |
| Share of low- or zero-carbon primary energy | No policy case | 14% | 14% | 15% | 14% |
| | Core scenario | 15% | 18% | 26% | 38% |

EPA's analysis of H.R. 2454 shows that the bill would transform the structure of energy production and consumption, moving the economy from one that is relatively energy inefficient and dependent on highly-polluting energy production to one that is highly

[17] Ranges shown for the core policy run reflect the values for the two CGE models (ADAGE and IGEM) used in the EPA analysis of H.R. 2454. This range only reflects the differences in the models, and does not reflect the other scenarios or additional uncertainties..



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energy efficient and powered by advanced, cleaner, and more domestically-sourced energy. Increased energy efficiency and reduced demand for energy resulting from the policy mean that energy consumption levels that would be reached in 2015 without the policy are not reached until 2040 with the policy. The share of low- or zero-carbon primary energy (including nuclear, renewables, and CCS) would rise substantially under the policy to 18% of primary energy by 2020, 26% by 2030, and to 38% by 2050, whereas without the policy the share would remain steady at 14%. Increased energy efficiency and reduced energy demand would simultaneously reduce primary energy needs by 7% in 2020, 10% in 2030, and 12% in 2050. Petroleum primary energy use declines by 0.4 million barrels per day in 2020, 0.7 million barrels per day in 2030, and 1.6 million barrels per day in 2050. Electric power supply and use, and offsets represent the largest sources of emissions abatement under H.R. 2454.

Electric power supply and use are an important part of achieving emission reductions under cap-and-trade programs and are likely to represent the largest source of emissions abatement under S. 1733, based upon previous EPA modeling. The power sector is a large source of cost-effective emission reductions, driven by the long-term caps placed on emissions of greenhouse gases and the resulting price signal, which transforms the nature of electric supply from higher-emitting technologies to lower- and non-emitting technologies like renewables, nuclear, and coal with CCS technology. Where perceived by consumers, the price signal also encourages improvements in end-use energy efficiency. By 2050, most fossil electricity generation would be capturing and storing $CO_2$ emissions and the power sector would largely be de-carbonized.

The timing and magnitude of the reductions within this sector largely depend on the existing coal fleet, which provides almost 50% of our nation's electricity. The allowance price is the most critical element, and much of the existing fleet remains economic at $CO_2$ prices below $20 per ton. Additional policies and incentives beyond the pure cap-and-trade program, such as CCS bonus provisions or aggressive renewable generation requirements, can reduce the economic impact of the program on the existing coal fleet by lowering the allowance price. However, unless these policies are targeted to overcome specific market failures (such as suboptimal private investment in research and development), such provisions are likely to increase the overall costs of achieving emission reductions.

In the core scenario of EPA's analysis of H.R. 2454 estimated allowance prices were $13/t$CO_2$e in 2015 and $16/t$CO_2$e in 2020. Across scenarios, the allowance price ranged from $13 to $24/t$CO_2$e in 2015 and from $16 to $30/t$CO_2$e in 2020.

EPA estimated that H.R. 2454 would have a relatively modest impact on U.S. consumers assuming the bulk of revenues from the program are returned to households. With or without H.R. 2454, household consumption will continue to grow. Average household consumption is reduced by less than one percent in all years relative to the no policy case. On per household basis, these costs are $0.23 to $0.29 per day in 2020 and $0.76 to $1.00 per day in 2030. The average annual household consumption loss, calculated as the annual net present value cost per household with a discount rate of 5% and averaged over



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the 2010-2050 time period, is estimated to be $80 to $111 dollars per year relative to the no policy case. This represents 0.1 to 0.2 percent of household consumption. These costs include the effects of higher energy prices, price changes for other goods and services, impacts on wages and returns to capital. Cost estimates also reflect the value of some of the emissions allowances returned to households, which offsets much of the cap-and-trade program's effect on household consumption. The cost estimates do not account for the benefits of avoiding the effects of climate change. A policy that failed to return revenues from the program to consumers would lead to substantially larger losses in consumption.

In the core scenario of EPA's H.R. 2454 analysis, electricity prices are unchanged in 2020 due to the assumption that allocations to LDCs are used to prevent electricity price increases. In 2030, due to the phase out of the LDC allocation, the electricity price is estimated to increase by 13% relative to the reference scenario. Actual household energy expenditures increase by a lesser amount due to reduced demand for energy. In 2020, the average household's energy expenditures (excluding motor gasoline) are estimated to decrease by 7% relative to the reference scenario, and in 2030 household energy expenditures are estimated to increase by 2%. In ADAGE, energy expenditures represent approximately 2% of total consumption in 2020, falling to 1% by 2050 in all scenarios.

The economic literature shows small variations in the gross costs of climate policy across regions. Data from two recent economic studies, published by researchers at the National Bureau of Economic Research (NBER) and Resources for the Future (RFF), both indicate that differences in gross cost by region are modest. These studies did not specifically examine the allowance allocation provisions of H.R. 2454. Thus, the comparisons displayed ignore the cost-mitigating effects of those provisions. The NBER study finds only small regional differences. The increase in households' spending would range from 1.9% of annual income (East South Central region) to 1.5% (West North Central Region) (Hassett, et al., 2008). The RFF study also finds only small regional differences. The increase in households' spending would range from 1.6% of annual income (Ohio Valley) to 1.3% (California, New York, and the Northwest) (Burtraw, et al., 2009).

**Importance of Modeling Assumptions**

All analyses of climate change legislation must make assumptions, and these assumptions will inevitably impact the estimated costs of the legislation. Assumptions about economic growth in the reference case will influence the resulting emissions in the reference case, and determine the amount of abatement required to comply with the cap.[18] Assumptions about the cost and availability of technology influence estimates of the marginal cost of abatement from covered sources. Assumptions about the cost and availability of offsets influence the amount of abatement from non-covered sources that can be used to reduce the amount of abatement from covered sources. Assumptions

[18] Fawcett et al., forthcoming, discusses how reference case emissions growth influences the cost estimates from the five models that participated in the Stanford Energy Modeling Form 22 U.S. transition scenarios study.



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about climate policies adopted by other countries influence the cost and availability of international offsets, as well as the cost of globally traded energy goods. All of these assumptions will influence the estimated cost of climate policy. Most analyses of climate legislation contain multiple scenarios designed to highlight the assumptions and policy design choices that influence the estimated cost of the policy. In this section we discuss some sensitivity scenarios that highlight these important assumptions and uncertainties.

*Sensitivities on Offset Availability*

There are many institutional design issues, including the measurement, monitoring, reporting and verification requirements, surrounding estimates of offset availability. These issues must be addressed to ensure that the offset reductions are truly incremental, and represent real reductions. The EPA analysis of H.R. 2454 assumes that the institutions are put in place to process the domestic and international offsets needed to realize reductions on the magnitude shown in the analysis. Additionally, the cost and availability of offsets, particularly international offsets, is one of the greatest uncertainties in forecasting the cost of climate legislation. The U.S. will not be the only buyer of international offset credits, and the price of those credits will depend greatly on the competing demand for those credits. The stringency of climate policies adopted by other countries, the types of restrictions they place on international offset credits, and their expected reference case emissions growth all will influence the competing demand for international offset credits and the resulting price. Additionally, there is uncertainty on the supply side for both domestic and international credits that will influence the cost and availability of offsets.

All analyses that have looked at the issue have shown that the availability of offsets is one of the most important factors influencing allowance prices. EPA's analyses of the Waxman-Markey discussion draft and of H.R. 2454 showed that eliminating international offsets increased allowance prices by 96 and 89 percent respectively (EPA 2009a,b). MIT's analysis of H.R. 2454 examined two cases: a full offsets case with the full two billon metric tons of offsets available in each year, and a medium offsets case where the amount of available offsets ramp up linearly from zero in 2012 to the full two billon tons in 2050. The MIT analysis showed that the allowance price in the medium offsets case was 193 percent higher than the allowance price in the full offset case (MIT 2009). EIA's analysis of H.R. 2454 showed that compared to their 'basic' case,[19] the 'high offsets' case reduced allowance prices by 35 percent, and the 'no international offsets' case increased allowance prices by 64% (EIA 2009).

Offsets can have such a large impact on allowance price because, if they are able to provide low cost abatement from uncovered sources, they have the potential to greatly reduce the amount of emissions reductions needed from covered sources. The caps in S. 1733 allow covered sources to emit 131 $GtCO_2e$ cumulatively from 2012 through 2050. If the two billion tons of offsets allowed annually under H.R. 2454 were all used,

[19] It should be noted that in EIA's analysis of H.R. 2454, their 'basic' case allowed fewer offsets than were used in the core case of EPA's analysis of H.R. 2454.



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cumulative emissions from covered sources would be allowed to be 60 percent (78 $GtCO_2e$) higher.

Both H.R. 2454 and S. 1733 allow for unlimited banking of allowances, and most modeling of H.R. 2454 assumes that banking does indeed occur. Because of the possibility of banking, the cumulative number of offsets available over the entire time horizon drives how the availability of offsets influences allowance prices, not the particular time path of when that cumulative amount of offsets is available. EPA's analysis of H.R. 2454 showed that delaying international offsets availability by 10 years resulted in only a three percent increase in allowance prices, because the cumulative amount of international offsets used was only reduced by four percent as a result of the 10 year delay, and firms would respond by banking fewer allowances in the near term and using more offsets in the years after they became available. It is important to note that these results are premised on optimal banking behavior over a 40-year period. Any restrictions on banking, limitations to credit to enable banking, or myopia (not looking beyond next 20 years would be sufficient myopia), would alter these results.

*Technology Sensitivities*

Another major source of uncertainty about the costs of climate change legislation is the cost and availability of low or zero-carbon technologies. Many analyses include sensitivities on the penetration of key technologies. In EPA's analysis of H.R. 2454, limiting nuclear power to reference case levels increased allowance prices by 15 percent relative to the core scenario. In EIA's analysis of H.R. 2454 the 'high cost' case, which assumed that the costs of nuclear, fossil with CCS, and biomass generating technologies are 50 percent higher than in the 'basic' case, had an allowance price 12 percent higher than the 'basic' case. In both of these analyses, the allowance price increases resulting from the restricted or high cost technology scenarios was somewhat dampened by the ability to increase the usage of offsets. The uncertainties surrounding the penetration of key technologies involve technical uncertainties about the cost and performance of new technologies, political uncertainties about the regulatory infrastructure required to license and permit the technologies, as well as uncertainties about the public's willingness to accept the expansion of technologies such as nuclear power and coal with CCS.

*High Cost Scenarios*

The highest cost scenarios included in various modeling efforts generally involve both restrictions on offsets and limitations on technology. In EIA's analysis of H.R. 2454, the 'no international / limited' case combines the offsets limits and high technology costs from their 'no international offsets' and 'high cost' cases. In this scenario, allowance prices are 194 percent higher than in the 'basic' case. This increase is significantly greater than when just technology is restricted, as offset usage can no longer increase to make up for the higher cost of abatement within covered sectors. EPA's past analyses show a similar result, where eliminating international offsets and restricting nuclear and CCS technologies significantly increases allowance prices (e.g., over 180 percent). The high allowance prices would increase the price U.S. firms would be willing to pay for



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international offset credits and make it more likely that international offset credits would be available. These scenarios are intended to represent the upper range of costs and can be included in analyses as part as a range of sensitivities designed to highlight important uncertainties and drivers of costs.

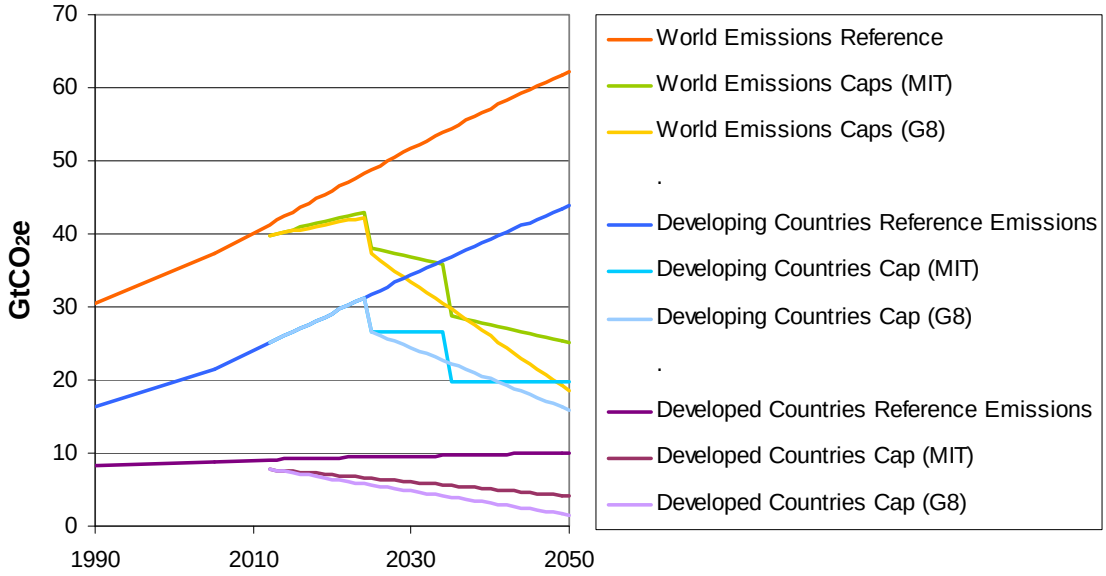
*International Action*

One development since EPA conducted its analysis of H.R. 2454 is that at the July 9, 2009 Major Economies Forum, "the G8 leaders agreed to reduce their emissions 80% or more by 2050 as its share of a global goal to lower emissions 50% by 2050, acknowledging the broad scientific view that warming should be limited to no more than two degrees Celsius." A set of international policy assumptions that is consistent with the G8 agreement is as follows:

- Developed countries follow an allowance path that falls linearly from the Kyoto Protocol emissions levels in 2012 to 83% below 2005 in 2050.
- Developing countries adopt a policy beginning in 2025 that caps emissions at 2015 levels, and linearly reduces emissions to 26% below 2005 levels by 2050.
- The combination of U.S., developed, and developing country actions caps 2050 emissions at 50% below 2005 levels.

This is a more stringent policy internationally than what was assumed in EPA's analysis of H.R. 2454, which were based on the international policy assumptions used in the 2007 MIT report, "Assessment of U.S. Cap-and-Trade Proposals." Figure 4 below depicts the cap levels in both sets of international policy assumptions for non-U.S. developed countries and developing countries, along with the total world emissions that result from the developed and developing country caps along with U.S. action.

*Figure 4 –MIT and G8 International Climate Policy Assumptions*



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While this change in assumptions about climate change policies adopted by other countries is not a change to the bill, assuming that these international goals are met would affect the cost of both H.R. 2454 and S. 1733 in much more substantial ways than any differences in the bills themselves. The tighter caps assumed for other countries under the G8 agreement would increase their demand for GHG abatement, and thus raise the price for international offset credits. Adopting these new assumptions about international action would likely raise EPA's projected price of international offsets by approximately one quarter, and also significantly reduce the amount of international offsets purchased domestically. This increase in the price of international offsets would also result in an equivalent increase in domestic allowance prices. Note that more aggressive international action, while raising the cost of the U.S. climate policy, also benefits the U.S. because it leads to more global greenhouse gas reductions, resulting in smaller increases in temperature. Additionally, seriously engaging our trade partners, as envisioned in the G8 statement, embodied in U.S. international climate policy, and reflected in the latest modeling analyses, should decrease estimated leakage impacts.

**Distributional Impacts**

The way in which allowances are allocated (auctioned or given away) and how any revenues are used affect the distribution of costs of a GHG cap-and-trade policy across households. For example, the free distribution of allowances to firms tends to be very regressive: higher income households are less affected and may even be made better off, while lower income households could be worse off under a policy that distributes most or all allowances to industry. This is because the asset value of the allowances flow to households in the form of increased stock values or capital gains, which are concentrated in higher-income households. Revenues can also be redistributed in the form of lower payroll or corporate taxes. Such methods of distributing allowances can lower the overall cost of the policy by reducing distortions in the economy due to taxation. However, they may also be regressive because corporate tax reductions benefit higher-income households, and the lowest-income households do not pay federal income taxes (though an approach that uses a combination of income tax reductions and per-capita rebates can be designed to be progressive). Auctioning allowances with per-capita lump-sum distribution of revenues to households is often the least regressive cap-and-trade policy analyzed and is usually shown to be progressive.

Several recent cap-and-trade proposals (including H.R.2454 and S.1733) attempt to attenuate costs to households by allocating a percentage of allowances to consumers for free via local electricity distribution companies (LDCs). Because these allowances are allocated on the basis of electricity use, industrial, commercial, and residential consumers will benefit from electricity prices being kept low. However, this form of allowance allocation can dampen the price signal that induces consumers to conserve electricity, which increases the economy-wide cost of complying with the cap since greater emission reductions have to be achieved by other sectors of the economy. While electricity prices

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do not rise as much with LDC allocations, consumers will face higher prices for other energy-intensive goods and services.

The models EPA uses to analyze the costs of the policy assume there is one representative household, so distributional implications cannot be assessed directly within the general equilibrium framework. However, two recent studies have examined the incidence of costs across income classes of the cap-and-trade program in H.R.2454, which is similar in stringency and in the allocation of allowance value to S.1733 (CBO, 2009; Blonz and Burtraw, 2009). Before accounting for the way in which allowances are allocated or revenues are redistributed, these analyses show that the cap imposes higher welfare costs (as a percentage of household income) on lower income deciles. This is an expected result since lower income households spend a higher fraction of their incomes on energy-intensive goods.

Accounting for the distribution of allowance value counteracts some of the welfare costs for all households and presents a different picture of the net welfare impacts of the policy across income groups. Both of these studies find an inverted U-shaped relationship between net welfare loss and income: lower income households are on net better off than without the policy and the wealthiest households bear a smaller burden or are virtually unaffected by the policy. The highest costs as a percentage of income are borne by middle to upper-middle income households.

For example, Blonz and Burtraw (2009), account for 56 percent of emissions allowances in H.R.2454, including allowance value that is allocated to electricity and natural gas LDCs, home heating oil providers, and low-income families, find that in 2015 the benefit of these allowance allocation approaches more than offset the higher cost of goods and services resulting from the policy for households in the bottom two income deciles. The third and tenth income deciles experience a smaller net cost than the average household under the policy. It is the households in the middle to upper-middle income deciles that bear the highest costs as a portion of household income. A full accounting of allowance allocation would likely exacerbate the overall regressiveness of the policy since the undistributed allowance allocations are primarily allocations to industry, which will tend to benefit shareholders, most of whom are in the upper income deciles.

The Congressional Budget Office accounts for a great share of the distribution of emission allowances and finds qualitatively similar results in their analysis of H.R. 2454. CBO (2009) estimates the loss in purchasing power[20] that would be faced by households in each fifth (quintile) of the population arrayed by income (and adjusted for household size). In 2020, *gain* of about 0.7 percent of after-tax income, or about $125 measured at 2010 income levels. The largest loss would be experienced by households in the middle and fourth income quintile, about 0.5-0.6 percent of income, or about $310-375 at 2010 income levels. Households in the highest income

[20] CBO calculates the loss in purchasing power as the costs of complying with the policy (including the cost of purchasing allowances and offsets, and of reducing emissions—costs that businesses would generally pass along to households in the form of higher prices) minus the compensation that would be received as a result of the policy.



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quintile would see a small *loss*[21]

Different methods of distributing the allowance value will yield different distributional results. For example, Blonz and Burtraw (2009) compare their analysis of H.R. 2454 to an alternative allocation of the same 56 percent of allowances in which the allocation to LDCs is limited to residential consumers of electricity and natural gas. The proposed allocation scheme on behalf of residential electricity and natural gas customers accounts for approximately 15 percent of allowance value, leaving the remaining 41 percent to be distributed as a per-capita dividend. They find this alternative would smooth out the burden across households while simultaneously lowering the overall costs for households in the third through ninth income deciles. The bottom two income deciles are still better off than in the no policy case.

Analyzing a policy similar in stringency to H.R. 2454 and S. 1733, Burtraw et al. (2009) find that if all of the allowances are auctioned and returned to consumers as a nontaxable dividend, the bottom three income deciles are on net better off than without the policy. The majority of costs as a portion of household income are born by households in the sixth to tenth income deciles. They also note that if the lump sum rebate were taxable, the policy would be more progressive. This is because, assuming budget neutrality, the pre-tax lump sum rebate would be increased by the average income tax rate for all households. Poorer households would then hold a larger after-tax rebate than wealthier households.

If the rebate to low income households instead were redistributed on a lump sum non-taxable rebate across all households, the policy would be less progressive. While less progressive, it does have the feature that the net burden would be levelized across households on a percentage-of-income basis. If a greater share of the allowance value were returned to households based on their energy consumption rather than through a lump-sum rebate, the incidence model would likely show the overall policy cost would increase while the change in the distribution of costs is less clear.

EPA is currently developing the capacity to model the distributional impacts of the allowance allocations in existing bills using an incidence model and methodology similar to the one described in Burtraw et al. (2009).

**Temperature Impacts**

In previous analyses, EPA has looked at the impact of U.S. policy combined with the policies assumed for developed and developing countries on global greenhouse gas

[21] CBO goes on to show that H.R. 2454 would have different impacts across households in 2050, by which time most of the value of allowances would flow to households directly. There would be a larger gain in purchasing power (as a percentage of after-tax income) for the lowest income households and a larger loss for the highest income quintile compared to the middle income groups. The largest burden would still be experienced by households in the middle and next-to-highest income quintiles.



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concentrations. However, the assumptions used in earlier analyses for what policies other countries would adopt are not consistent with the recent G8/Major Economies Forum goal discussed above. EPA has now analyzed, using the MiniCAM and MAGICC models, how U.S. targets consistent with the President's FY 2010 budget proposal (14% below 2005 in 2020, and 83% below 2005 in 2050)[22] combined with international action consistent with the G8 agreement could affect global $CO_2e$ concentrations and temperatures.

Figure 5 below shows global $CO_2e$ concentrations through 2100 assuming a climate sensitivity (CS) of 3.0.[23] The CS is the equilibrium temperature response to a doubling of $CO_2$, and a CS of 3.0 is deemed the "best estimate" by the IPCC.[24] The figure presents three scenarios:

(1) Reference: no climate polices or measures adopted by any countries.
(2) G8 - International Assumptions: consistent with G8 agreement to reduce global emissions to 50% below 2005 levels by 2050. U.S. and other developed countries reduce emissions to 83% below 2005 levels by 2050, and developing countries cap emissions beginning in 2025, and return emissions to 26% below 2005 levels by 2050. All countries hold emissions targets constant after 2050.
(3) Developing Countries After 2050: US and developed countries same as G8 scenario. Developing countries adopt policy in 2050 holding emissions constant at 2050 levels.

In the reference scenario, $CO_2e$ concentrations in 2100 would rise to approximately 936 ppm.[25] If the U.S. and other developing countries took action to reduce emissions to 83% below 2005 levels by 2050, and developing countries took no action until 2050, then $CO_2e$ concentrations in 2100 would rise to approximately 647 ppm. If the G8 goals are met, then $CO_2e$ concentrations would rise to approximately 485 ppm in 2100. It should be noted that $CO_2e$ concentrations are not stabilized in these scenarios. To prevent concentrations from continuing to rise after 2100, post-2100 GHG emissions would need to be further reduced. For example, stabilization of $CO_2e$ concentrations at 485 ppm would require net $CO_2e$ emissions to go to zero in the very long run after 2100.

[22] The cumulative GHG emissions under the cap from 2012 – 2050 under the President's FY 2010 budget proposal are 133.9 $GtCO_2e$. This is 1% greater than the 132.6 $GtCO_2e$ in H.R. 2454, and 2% greater than the 130.6 $GtCO_2e$ in S. 1733.
[23] The climate sensitivity is the equilibrium change in global mean near-surface air temperature that would result from a sustained doubling of the atmospheric $CO_2e$ concentration.
[24] IPCC WG1 SPM (2007): "[Climate sensitivity] is *likely* to be in the range 2°C to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded…"
[25] Global $CO_2$ concentrations in 2008 were 385.6 ppmv (see Tans (2009)) compared with pre-industrial concentrations of 280 ppmv (see IPCC WG1 SPM (2007)). According to the IPCC, historic $CO_2$ concentrations have not exceeded 300 ppmv in the last 650,000 years.



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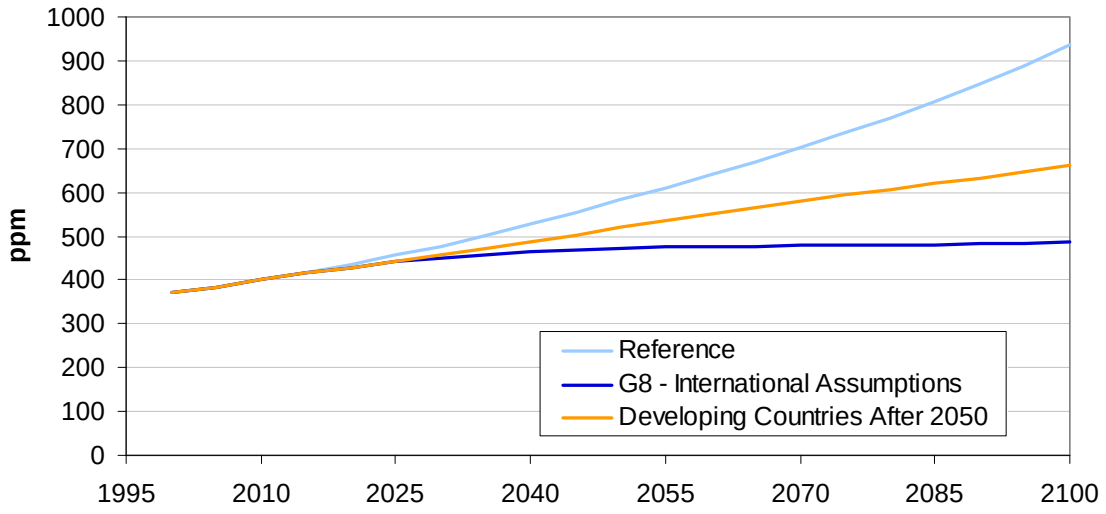
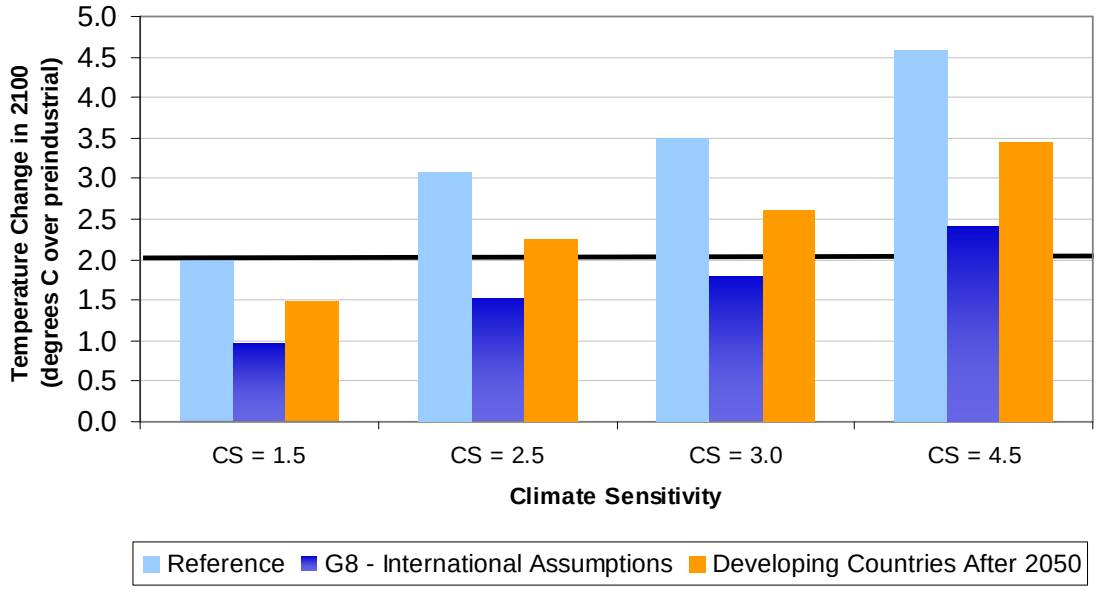
*Figure 5 – $CO_2e$ Concentrations (Climate Sensitivity = 3.0)*




Given the $CO_2e$ concentrations for the various scenarios, we can also calculate the observed change in global mean temperature (from pre-industrial time) in 2100 under different climate sensitivities. Assuming the G8 goals (reducing global emissions to 50% below 2005 by 2050) are met, warming in 2100 would be limited to no more than 2 degree Celsius (3.6 degrees Fahrenheit) above pre-industrial levels under a climate sensitivity of 3.0 or lower, as shown in figure 6 below.

*Figure 6 – Global Mean Temperature Change in 2100 by Scenario and Climate Sensitivity (CS)*



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It should be noted that the temperature change in 2100 in this scenario is not stabilized, so the observed change in global mean temperature in 2100 is not equal to the equilibrium change in global mean temperature. There are two reasons for this. First, while the G8 international goals stabilize global GHG emissions at 50% below 2005 levels, $CO_2$e concentrations and temperature are not stabilized. Determining an equilibrium temperature under any scenario requires additional assumptions about post-2100 emissions. If emissions remain constant post-2100, $CO_2$e concentrations will continue to rise. Equilibrium temperature would only be achieved after $CO_2$e concentrations are in equilibrium. Second, the inertia in ocean temperatures causes the equilibrium global mean surface temperature change to lag behind the observed global mean surface temperature change by as much as 500 years. Even if $CO_2$e concentrations in 2100 were stabilized, observed temperatures would continue to rise for centuries before the equilibrium were reached.

Continued GHG emissions reductions after 2100 could stabilize $CO_2$e concentrations at the 485 ppm levels achieved in 2100 in the G8 scenario. In order to achieve an equilibrium temperature change of 2 degrees (assuming CS = 3.0), $CO_2$e concentrations must be stabilized below 485 ppm, requiring continued abatement beyond the level needed to stabilize concentrations at 2100 levels. It would be possible to reduce $CO_2$e concentrations after 2100 below 485 ppm by even further reducing GHG emissions in the next century. An 'overshoot' scenario such as this would further reduce the equilibrium temperature change, making it possible to achieve the 2 degrees C target even with a climate sensitivity of 3.0.

While this analysis doesn't quantify the impacts of higher temperatures and other effects of increasing GHG concentrations, the U.S. Global Change Research Program (in its June 2009 report, "Global Climate Change Impacts in the United States") described the impacts that we are already seeing and that are likely to dramatically increase this century if we allow global warming to continue unchecked. In the report, it documents how communities throughout America would experience increased costs, including from more sustained droughts, increased heat stress on livestock, more frequent and intense spring floods, and more frequent and intense forest wildfires.

**Conclusion**

EPA's analysis of S. 1733 demonstrates that the costs of the bill are likely to be quite similar to the costs of H.R. 2454. While there are some minor differences in the bills in several areas that will likely result in slightly higher costs for S. 1733, these differences are overshadowed by the fundamental similarities in approach, caps, offsets, and other critical design parameters that affect the costs.

In table 5 below, we depict the differences between the bills with respect to these fundamental design parameters and illustrate for each element the degree to which we expect similarities or differences in the costs of S. 1733 compared to H.R. 2454. The evidence for the finding in the table is drawn from the preceding text in this paper, which clearly shows the large similarities between the two bills.



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*Table 5: Summary of Impacts of Key Provisions in S.1733*

| Key Provisions | H.R. 2454 | S. 1733 | Impact of Differences in S. 1733 on Modeled Costs & Price from H.R. 2454 |
|---|---|---|---|
| Cap Level | 17% below 2005 in 2020; cumulative number of allowances are 132.2 gigatons $CO_2e$ | 20% below 2005 in 2020; cumulative number of allowances are 130.6 gigatons $CO_2e$ | Small increase in both allowance prices and costs |
| Coverage | Differences are negligible | | |
| Offset Limits | 2 billion ton limit overall;<br>1 billion ton domestic limit;<br>1 billion ton international limit;<br>Up to an extra 0.5 billion tons of international offsets if domestic usage below 0.9 billion tons | 2 billion ton limit overall;<br>1.5 billion ton domestic limit;<br>0.5 billion ton international limit;<br>Up to an extra 0.75 billion tons of international offsets if domestic usage below 0.9 billion tons | Negligible, or small increase in both allowance prices and costs in low technology scenarios |
| Strategic Reserve | 2.7 billion cumulative allowances from 2012-2050.<br><br>Minimum reserve auction price is 60 percent above the 36-month rolling average of that year's emissions allowance vintage | 3.5 billion cumulative allowances from 2012-2050.<br><br>Minimum reserve auction price is $28 in 2012 rising at 5% through 2017 and rising at 7% thereafter. | Small increase in both allowance prices and costs if minimum reserve prices are not met<br><br>Changed conditions on minimum reserve auction price have the potential to provide better price certainty. |
| Energy Efficiency and Renewable Energy Provisions | Building codes, energy efficiency-related allocations, and Combined Efficiency and Renewable Energy Standard | Less stringent building codes, slightly lower energy efficiency-related allocations, and no Combined Efficiency and Renewable Energy Standard | Slight increase in allowance prices due to changes in energy efficiency provisions; a decrease in costs and price without the renewable energy requirements is possible to the extent that such requirements are binding in H.R. 2454 |
| Performance Standards | Standards for uncapped sources (e.g., landfills, coal mines, and natural gas systems) | Uncapped sources treated as domestic offsets | Small decrease in both allowance prices and costs, though U.S. cumulative emissions increase slightly |
| CCS Bonus | 5.32 billion allowances, fixed incentive for first 6 GW, reverse auction thereafter | 4.19 billion allowances, fixed advanced payment incentive for first 20 GW, reverse auction thereafter | Small increase in allowance prices due to smaller bonus allowance pool |
| Energy Intensive, Trade Exposed Industries | Differences are negligible | | |
| Transportation | Differences are negligible | | |
| Domestic Agriculture and Forestry Offsets | Differences are negligible | | |

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## Appendix

### Past EPA modeling analyses of Bills related to mitigating greenhouse gas emissions

Since 2005, EPA has released six analyses, including three for the 110th Congress. This appendix provides a list of the analyses, a brief description of the scenarios modeled for each, and a brief description of the models used for these analyses.

It is important to note that EPA is not alone in performing economic analyses of climate legislation. Within the U.S. government, the Energy Information Administration and the Congressional Budget Office have done analyses of recent legislative climate policy proposals. USDA has also developed analysis related to the role of agriculture in climate policy proposals. Outside of the U.S. government the Stanford Energy Modeling Forum has gathered together a number of models that have been widely used for climate policy analysis including: the Applied Dynamic Analysis of the Global Economy model (ADAGE) from the Research Triangle Institute; the Emissions Predictions and Policy Analysis model (EPPA) from the Massachusetts Institute of Technology; the Model for Emissions Reductions in the Global Environment (MERGE), from the Electric Power Research Institute; MiniCAM, from the Pacific Northwest National Laboratory / Joint Global Change Research Institute; the Multi-Region National Model - North American Electricity and Environment Model (MRN-NEEM), from Charles River Associates; and the Intertemporal General Equilibrium Model (IGEM), from Dale Jorgenson Associates (Fawcett *et al*., forthcoming).

***Analyses***:

- **Analysis of H.R. 2454 in the 111th Congress, the American Clean Energy and Security Act of 2009 – June 2009**
- **Preliminary Analysis of the Waxman-Markey Discussion Draft in the 111th Congress, The American Clean Energy and Security Act of 2009 – April 2009**
- **Analysis of Senate Bill S.2191 in the 110th Congress, the Lieberman-Warner Climate Security Act of 2008 – March 2008**
- **Analysis of Senate Bill S.1766 in the 110th Congress, the Low Carbon Economy Act of 2007 – January 2008**
- **Analysis of Senate Bill S.280 in the 110th Congress, The Climate Stewardship and Innovation Act of 2007 - July 2007**
- **Analysis of Senate Bill S.843 in the 108th Congress, Clean Air Planning Act - October 2005**

*Note: The "Waxman-Markey Discussion Draft" and H.R. 2454 were analyzed with updated models reflecting, among other changes, the AEO March 2009 reference case*

*which reflects the provisions of the Energy Independence and Security Act of 2007, but not those of the American Recovery and Reinvestment Act of 2009.*

***Scenarios Analyzed:***

**Analysis of H.R. 2454 in the 111th Congress, the American Clean Energy and Security Act of 2009 – June 2009**

1) EPA 2009 Reference Scenario
2) H.R. 2454 Scenario
3) H.R. 2454 Scenario without Energy Efficiency Provisions
4) H.R. 2454 Scenario with Output-Based Allocations
5) H.R. 2454 with Reference growth in Nuclear Power
6) H.R. 2454 Scenario without Output-Based Allocations or Energy Efficiency Provisions
7) H.R. 2454 Scenario without International Offsets

**Preliminary Analysis of the Waxman-Markey Discussion Draft in the 111th Congress, The American Clean Energy and Security Act of 2009 – April 2009**

1) EPA 2009 Reference Scenario
2) Waxman-Markey Scenario
3) Waxman-Markey Scenario with Energy Efficiency Provisions
4) Waxman-Markey Scenario with Output-Based Allocations
5) Waxman-Markey Scenario with No International Offsets

**Analysis of Senate Bill S.2191 in the 110th Congress, the Lieberman-Warner Climate Security Act of 2008 – March 2008**

1) EPA Reference Scenario
2) S. 2191 Scenario
3) S. 2191 Scenario with Low International Action
4) S. 2191 Scenario Allowing Unlimited Offsets
5) S. 2191 Scenario with No Offsets
6) S. 2191 Scenario with Constrained Nuclear and Biomass
7) S. 2191 Scenario with Constrained Nuclear, Biomass, and Carbon Capture and Storage
8) S. 2191 Scenario with Constrained Nuclear, Biomass, Carbon Capture and Storage, international targets “Beyond Kyoto” and a Natural Gas Cartel
9) Alternative Reference Scenario, assuming EIA “High Technology” case
10) S. 2191 Alternative Reference Scenario

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**Analysis of Senate Bill S.1766 in the 110th Congress, the Low Carbon Economy Act of 2007 – January 2008**

1) Core Reference Scenario
2) S. 1766 Scenario
3) S. 1766 Scenario without Technology Accelerator Payments (TAP)
4) S. 1766 Scenario with Ten Percent International Offsets
5) S. 1766 Scenario with Unlimited International Offsets
6) S. 1766 Scenario without TAP, and with Ten Percent International Offsets
7) S. 1766 Scenario without TAP, and with Unlimited International Offsets
8) S. 1766 Scenario without Carbon Capture and Storage Subsidy
9) S. 1766 Scenario without Tap, and with no Carbon Capture and Storage Subsidy
10) S. 1766 Scenario without Carbon Capture and Storage Subsidy and Low Nuclear
11) S. 1766 Scenario with Alternative International Action
12) High Technology Reference Scenario
13) S. 1766 High Technology Scenario
14) S. 1766 High Technology Scenario without TAP
15) S. 1766 High Technology Scenario with Ten Percent International Offsets
16) S. 1766 High Technology Scenario with Unlimited International Offsets
17) S. 1766 High Technology Scenario without TAP, and with Ten Percent International Offsets
18) S. 1766 High Technology Scenario without TAP, and with Unlimited International Offsets
19) S. 1766 High Technology Scenario without Carbon Capture and Storage Subsidy
20) S. 1766 High Technology Scenario without TAP, and without Carbon Capture and Storage Subsidy

**Analysis of Senate Bill S.280 in the 110th Congress, The Climate Stewardship and Innovation Act of 2007 - July 2007**

1) EPA Reference Scenario
2) S. 280 Senate Scenario
3) S. 280 Senate Scenario with Low International Action
4) S. 280 Senate Scenario allowing Unlimited Offsets
5) S. 280 Senate Scenario with No Offsets
6) S. 280 Senate Scenario with Lower Nuclear Power Growth
7) S. 280 Senate Scenario with No Carbon Capture and Storage

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**Analysis of Senate Bill S.843 in the 108th Congress, Clean Air Planning Act - October 2005**

*Note S. 843 was a bill addressing emissions from the power sector, and not an economy-wide approach like those above. The bill set a cap for carbon dioxide emissions from the power sector and allowed for domestic and international offsets to meet the cap. EPA analyzed those provisions of the bill with early versions of the models used for the analyses listed previously. A number of sensitivities were performed for the power sector components, but for the GHG analysis, only two scenarios were analyzed.*

1) Core Scenario – assuming Kyoto ends in 2012
2) Sensitivity Scenario – assuming Kyoto continues with no changes

***Models Used***

Applied Dynamic Analysis of the Global Economy Model (ADAGE)

ADAGE is a dynamic computable general equilibrium (CGE) model capable of examining many types of economic, energy, environmental, climate-change mitigation, and trade policies at the international, national, U.S. regional, and U.S. state levels. ADAGE is developed and run for EPA by RTI International. See the model homepage at http://www.rti.org/adage

Intertemporal General Equilibrium Model (IGEM)

IGEM is a model of the U.S. economy with an emphasis on the energy and environmental aspects. It is a dynamic model, which depicts growth of the economy due to capital accumulation, technical change and population change. IGEM is a detailed multi-sector model covering 35 industries. The model is developed and run by Dale Jorgenson Associates for EPA. See the model homepage: http://post.economics.harvard.edu/faculty/jorgenson/papers/papers.html

Non-$CO_2$ Greenhouse Gas Models

EPA develops and houses projections and economic analyses of emission abatement through the use of extensive bottom-up, spreadsheet models. These are engineering–economic models capturing the relevant cost and performance data on over 15 sectors emitting the non-$CO_2$ GHGs. The data used in the report are from *Global Mitigation of Non-$CO_2$ Greenhouse Gases* (EPA Report 430-R-06-005). www.epa.gov/nonco2/econ-inv/international.html

Forest and Agricultural Optimization Model – GHG (FASOM-GHG)

FASOM-GHG simulates land management and land allocation decisions over time to competing activities in both the forest and agricultural sectors. In doing this, it simulates the resultant consequences for the commodity markets supplied by these lands and,



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importantly for policy purposes, the net greenhouse gas (GHG) emissions. FASOMGHG is a multiperiod, intertemporal, price-endogenous, mathematical programming model depicting land transfers and other resource allocations between and within the agricultural and forest sectors in the US. The principal model developer is Dr. Bruce McCarl, Department of Agricultural Economics, Texas A&M University. The data used in the report are documented in: U.S. EPA, 2009. *Updated Forestry and Agriculture Marginal Abatement Cost Curves*. Memorandum to John Conti, EIA, March 31, 2009. See the model homepage: http://agecon2.tamu.edu/people.faculty/mccarl-bruce/FASOM.html

Global Timber Model (GTM)

GTM is an economic model capable of examining global forestry land-use, management, and trade responses to policies. In responding to a policy, the model captures afforestation, forest management, and avoided deforestation behavior.
The model is a partial equilibrium intertemporally optimizing model that maximizes welfare in timber markets over time across approximately 250 world timber supply regions by managing forest stand ages, compositions, and acreage given production and land rental costs. The principal model developer is Brent Sohngen, Department of Agricultural, Environmental, and Development Economics, Ohio State University. See the model website for GTM papers and input datasets:
http://aede.osu.edu/people/sohngen.1/forests/ccforest.htm#gfmod

Global Climate Assessment Model (GCAM, formerly MiniCAM)

The MiniCAM is a highly aggregated integrated assessment model that focuses on the world's energy and agriculture systems, atmospheric concentrations of greenhouse gases ($CO_2$ and non-$CO_2$) and sulfur dioxide, and consequences regarding climate change and sea level rise. The model is developed and run at the Joint Global Change Research Institute, University of Maryland. See the model homepage**:**
http://www.globalchange.umd.edu

Integrated Planning Model (IPM)

EPA uses the Integrated Planning Model (IPM) to analyze the projected impact of environmental policies on the electric power sector in the 48 contiguous states and the District of Columbia. IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector. The IPM was a key analytical tool in developing the Clean Air Interstate Regulation (CAIR) and was also used in the development of the Regional Greenhouse Gas Initiative (RGGI). The model was developed by ICF Resources and is applied by EPA for its Base Case. IPM® is a registered trademark of ICF Resources, Inc. EPA's application of IPM Homepage:
http://www.epa.gov/airmarkets/progsregs/epa-ipm/index.html

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