Modeling the Impact of a Carbon Tax On The Commercial Buildings Sector[1]

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ABSTRACT

This paper examines the impact of instituting an economy-wide tax on CO_2 emissions in the United States, focusing especially on the changes such a tax would have on the energy and carbon profile of the commercial buildings sector. Compared with the Reference case forecast, the "Main Tax + High Tech" scenario falls short of the goal of the Better Buildings initiative, but nearly meets the Waxman-Markey and Copenhagen carbon reduction goals. Because commercial buildings rely on electricity for a majority of their energy services, their carbon emissions are significantly reduced by the power sector's transition to lower carbon resources, motivated by the carbon tax. In terms of energy intensity, a carbon tax would deliver faster and deeper reductions in the commercial sector than in the rest of the economy. The effects of carbon taxes on commercial building energy efficiencies would be technologically transformational and geographically widespread. While energy expenditures would rise and more capital would be required for energy-efficiency upgrades, the avoided pollution would deliver more than $150 billion in benefits through 2035, and the reduced CO_2 emissions would avoid damages worth more than $100 billion over the same period. Finally, we show that better technology can cut the cost of saving energy, and the potential to consume less energy through better technology is amplified by a carbon tax.

Introduction

Reducing the threat of climate change will require providing the right incentives for behaviors and investments that drive a transition to a low-carbon emissions economy. One of the most effective actions countries could take to respond to climate change would be to provide a price for greenhouse gas (GHG) emissions that charges emitters for the damages caused by their actions. Carbon pricing is an important mechanism for providing companies and individuals with an incentive to invest in carbon abatement. Currently, GHGs can be emitted into the atmosphere for free in most countries, but the impacts of these emissions impose real costs on society. A carbon tax for reducing externalities from energy consumption could efficiently address technology deployment barriers connected to unpriced costs and benefits of carbon emissions. Such an approach increases the competitiveness of energy-efficient technologies and low-carbon

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fuels and power. Also, it encourages carbon capture and sequestration projects and technologies for reducing non-CO_2 GHGs. Implementation of such mechanisms would also help to address the policy uncertainty that has become an important barrier to the domestic deployment of low-carbon technologies.

While the U.S. does have a well-honed infrastructure and considerable experience with levying taxes generally, it does not have similar experience with pollution taxation. While carbon taxes have been debated, the U.S. has never levied a nation-wide carbon tax and no state has instituted a blanket carbon tax. However, there is a growing body of experience in several U.S. regions and in at least three U.S. localities – the San Francisco Bay Area Air Quality Management District, Babylon New York; and Boulder, Colorado. In addition, five Northern European countries, British Columbia, Canada, and Australia have instituted carbon taxes.

Methodology

The Georgia Institute of Technology's version of the National Energy Modeling System (GT-NEMS) is the principal modeling tool used in this study to examine the likely impacts of carbon taxes on the energy and carbon profile of commercial buildings, supplemented by spreadsheet calculations. Since the model is run on Georgia Tech computers, we call it the "GT-NEMS".[2] Specifically, we derive GT-NEMS from the version of NEMS that generated EIA's Annual Energy Outlook 2011 (EIA, 2011), which forecasts energy supply and demand for the nation out to 2035. The GT-NEMS "bottom-up" engineering and economic modeling approach is well suited to a carbon tax analysis focused on understanding the likely response of the commercial buildings sector (Cullenward, Wilkerson, and Davidian, 2009). By characterizing nearly 350 distinct commercial building technologies, and by enabling the separate analysis of nine Census division, ten end-uses (e.g., lighting and air conditioning), and eleven building types, GT-NEMS offers the potential for a rich examination of policy impacts. Top-down modeling of the energy economy produces fewer insights about the role of specific technologies and detailed end-use effects (Energy Modeling Forum, 2011).

An economy-wide tax on CO_2 emissions is examined, starting from $25/metric ton of CO_2 in 2015 with a 5% annual increase until 2035 (referred to as the "Main Tax" scenario). In addition, we use the technologies and availability within the EIA Commercial High Technology side case (called "High Tech"), which assumes more efficient equipment is available to consumers in the commercial buildings sector sooner. Finally, the EIA Commercial Best Technology case (called "Best Tech") was used to estimate a lower bound, which requires the purchase of the most efficient technologies (IEA, 2011).

[2] This nomenclature recognizes that even when the same NEMS code is used on two hardware systems with the supporting software programs – e.g., FORTRAN and the IHS Global Insights macroeconomic optimization tool – the model solution may be distinct from that of the EIA. The fact that the GT-NEMS Reference case is nearly identical to the EIA's Reference case indicates that the two models are essentially identical. For the policy scenarios, the authors modify the GT-NEMS code in order to reflect the impact of a carbon tax.

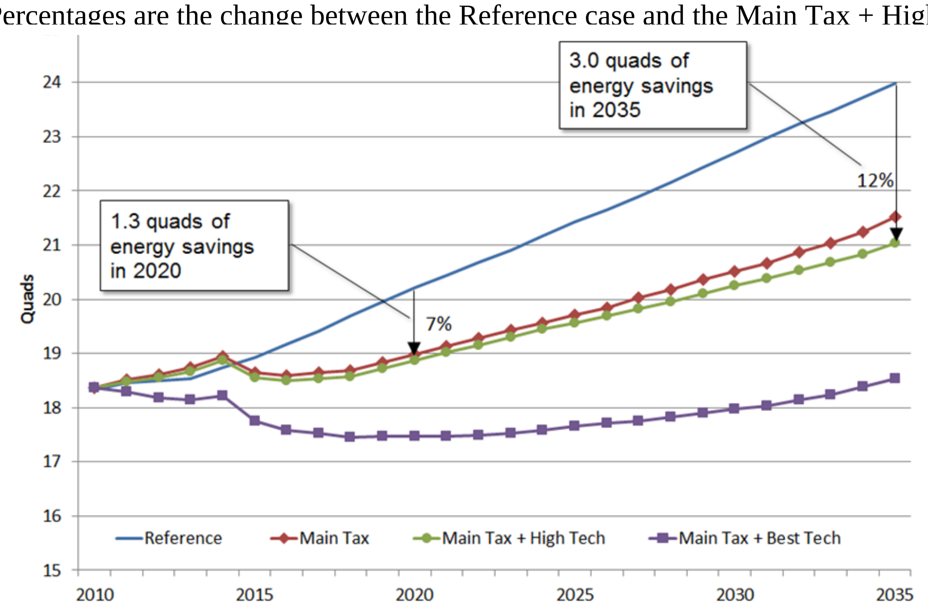
Impacts on Commercial Energy Consumption

The commercial buildings sector appears to respond quickly to a carbon tax. Following a pre-2015 rise in energy consumption relative to the Reference case (reflecting lower electricity rates resulting from higher coal use in the power sector), the Main Tax alone is estimated to achieve a 6% reduction in commercial building energy consumption in 2020 and a 10% reduction in 2035. When the same tax schedule is applied to the High Tech scenario, it achieves deeper energy consumption reductions: 7% in 2020 and 12% in 2035 (Figure 1). While meaningful, these reductions would fall short of the goal set by the Better Building initiative, to reduce commercial building energy use 20% by 2020 relative to 2010.

Despite the reductions in commercial energy use prompted by the Main Tech + High Tech scenario, commercial energy expenditures increase by 12% in 2020 and by 20% in 2035. This reflects rising energy prices. In the Main Tax + High Tech case, natural gas prices in the commercial sector increase by 33% above the Reference case. This causes a 4% decline in demand for natural gas from commercial buildings compared to the Reference case. A similar increase in electricity rates precipitates a much greater drop in demand (an 11% decrease in commercial sector electricity consumption relative to the Reference case). An analysis of implicit price elasticities of demand suggests an increasing sensitivity to rising electricity prices and a growing propensity for consumers to switch to natural gas as electricity prices rise. As Newell and Pizer (2008) note, “The microeconomic literature on energy demand in the commercial sector is not very deep” (p 528). As a result, it is difficult to draw comparisons of elasticities based on other studies, although an expanded discussion of this is provided in Brown, et al., 2012.

Figure 1. Commercial Energy Consumption (in Quads): Carbon Tax Scenarios Versus Reference Case

(Note: Percentages are the change between the Reference case and the Main Tax + High Tech case.)



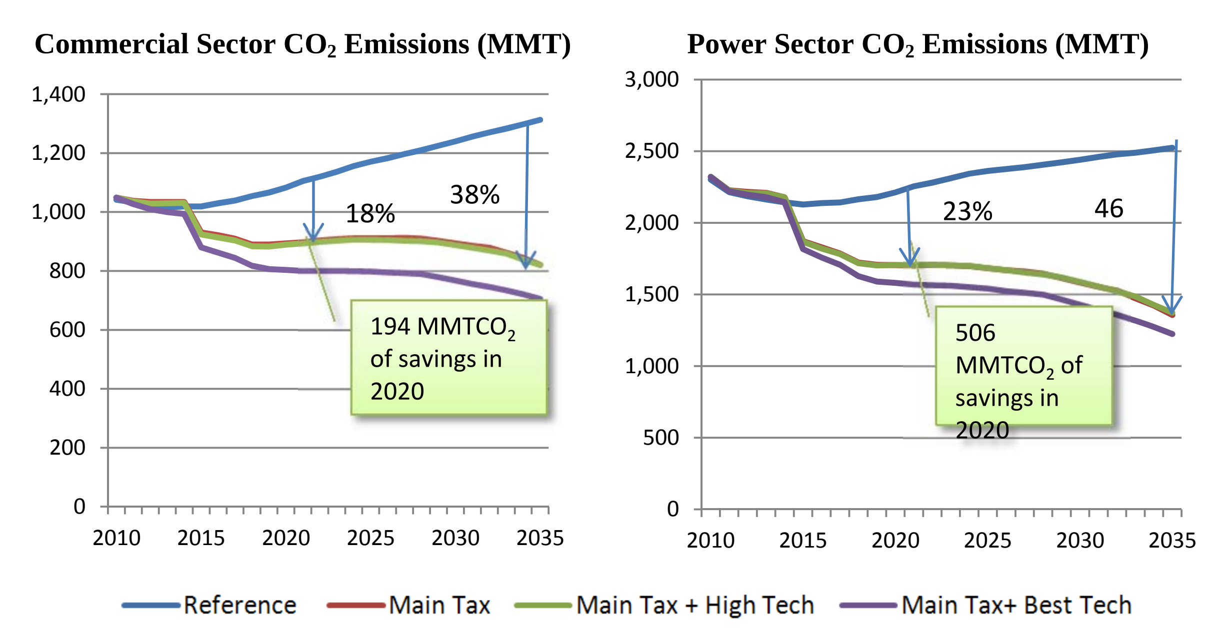
Impacts on CO_2 Emissions from Commercial Buildings

Though a carbon tax could produce a meaningful reduction in energy consumption by U.S. commercial buildings, the associated carbon emissions could be much more significant. Our analysis suggests that in the Main Tax + High Tech case, commercial buildings would reduce their CO_2 emissions by 38% relative to the Reference case by 2035 (Figure 2). The emission reductions vary for the two major fuels used in the sector. Natural gas related CO_2 emissions fall by 4% in 2035 relative to the Reference case while the electricity related CO_2 emission fall by 46%.

The results indicate that carbon emissions associated with commercial buildings are deeply affected by the choice of energy sources to generate electricity. The share of coal, the most carbon-intensive fuel, declines significantly in the Main Tax + High Tech case (25%) compared to the Reference case (47%) between 2015 and 2035. At the same time, the use of renewable energy increases, especially in the later years, rising from a 2035 share of 14% in the Reference case to 24% in Main Tax + High Tech case. Overall, the power sector reduces its CO_2 emission by 46% in 2035.

As a result, the impact of a carbon tax on CO_2 emissions from commercial buildings is much more significant than its impact on energy consumption. A decomposition analysis indicates that reduced CO_2 emissions from the power sector accounts for over three quarters of the 38% emission reduction associated with commercial buildings in 2035.

Figure 2. CO_2 Emission Reductions from the Commercial Buildings and Power Sectors



The model also projects that even with only a carbon tax, the commercial sector would be able to achieve deeper and faster reductions in energy intensity than the rest of the economy. In the Main Tax case, by 2020, energy use per square foot of commercial buildings would decline by 5.8%, while energy use per dollar of GDP would decline by only 3.3%. Changes in energy intensity in other sectors – also in 2020 and compared with the Reference case – further illustrate the greater responsiveness of commercial buildings to the Main Tax policy:

- The residential sector's energy intensity (measured in thousand Btu/sq ft) would decline by 4.7%
- The energy intensity of the industrial sector (measured by energy use per dollar of shipment) would decrease by a modest 2.3%
- The transportation sector's energy efficiency (measured in miles/gallon for on-road new light-duty vehicle) would improve by only 0.5%.

This declining responsiveness of energy intensity across sectors of the economy reflects the carbon intensity of the fuels that dominate each sector. From these comparisons, one could conclude that the Main Tax + High Tech scenario might be an effective strategy for improving the energy efficiency of commercial buildings, but a single economy-wide carbon tax could have quite uneven effects across the various sectors of the economy.

The societal benefits of avoided emissions, including CO_2 and criteria pollutants (SO_2, NO_x, $PM_{2.5}$, and PM_{10}), are estimated using published values from Interagency Working Group (EPA, 2010) and the National Research Council (2010). In 2020, avoided CO_2 and criteria emissions are valued at $3.0 billion and $7.7 billion ($-2009), respectively. By 2035, these same values are $45.7 billion and $21.1 billion. The avoided pollution would deliver more than $150 billion in benefits through 2035, and the reduced CO_2 emissions would avoid damages worth more than $100 billion over the same period.

Technology Shifts

Under the Main Tax + High Tech, energy consumption falls in all ten of the end-uses examined here (space heating, space cooling, water heating, lighting, ventilation, cooking, refrigeration, PC office equipment, non-PC office equipment, and miscellaneous). In addition, the relative importance of natural gas in meeting energy demand grows because of the trend toward fuel switching from electric to natural gas space heating.

The technology trends described in the Main Tax + High Tech scenario would bring about a significant increase in the average energy efficiency of the equipment used in commercial buildings. Of particular note, electric water heating efficiencies increase in the first decade because of a surge of improved heat pump and solar water heaters. That trend strengthens in the last decade when electric resistance water heaters are largely eliminated from the marketplace. Although lighting efficiencies are seen as improving only slightly above the Reference case in the first decade (when new federal standard mandate more efficient lighting beginning in 2012), by the second decade, the onset of light-emitting diodes (LED) light bulbs and super fluorescents in the Main Tax + High Tech scenario would increase the efficiency of lighting by an estimated 22% by 2035, above and beyond the Reference case.

The shift to more efficient technologies throughout the major end-uses is a clear trend in Table 1. Analysis of these shifts identifies four underlying transformations

- First, carbon taxes shift energy use from less efficient to more efficient classes of technology. For example, between 2010 and 2020, wall and window air conditioners (AC) are replaced by mid-efficiency (3.28 COP) rooftop AC units. In the same timeframe, we see less-efficient air source heat pumps (COP 3.3) losing out to ground source heat pumps (GSHPs) with a higher efficiency (COP 3.5). This transition is enabled by an IRS-implemented incentive that allows for accelerated depreciation of high-efficiency GSHPs, using a 5-year tax schedule. Similarly, the standard electric water heater is displaced by heat pump water heaters. This transition is accelerated by a new regulation going into effect in 2016 that will require electric storage water heaters with a capacity of 55 gallons or more to have efficiencies equivalent to heat pumps. In addition, the standard F32T8 electronic ballast that operates 4-foot fluorescent lamps is displaced by light-emitting diodes. (Not shown is the transition currently underway from T12 magnetic ballasts to the greatly improved T8 electronic ballasts.)

- Second, the carbon tax scenario produces cost savings by enabling consumers to move from more expensive to less expensive high-efficiency equipment within the same class of technology. This effect is illustrated in 2020 and in 2035 when consumers shift service demand from an earlier-generation, more expensive rooftop air conditioner to a later generation, less expensive rooftop AC unit with the same efficiency (from $72 to $67/1000 Btu Out/hour for unit with a COP of 3.28 ($-2007)).

- Third, carbon taxes enable consumers to gravitate to more efficient models within the same class of technology. As an example, in electric space heating, there is a second-tier of winners in 2035; centrifugal (COP 7.0) and reciprocating (COP 3.2) chillers that enter the market in 2020 gain market share against the less efficient centrifugal (COP 4.69) and reciprocating (COP 2.34) chillers first available in 2003.

Table 1. Technology Shifts:
Main Tax + High Tech Scenario vs Reference Case

End Use	2010-2020	2020-2035
Electric Space Heating		
Ascendent Technologies	Ground source heat pumps (COP 3.5)	High efficiency air source heat pumps (COP 3.8)
Declining Technologies	Less-efficient air source heat pumps (COP 3.3)	Less-efficient air source heat pumps (COP 3.3)
Natural Gas Space Heating		
Ascendent Technologies	High efficiency furnaces (94%) and boilers (95%)	High efficiency gas furnaces (94%) and boilers (95%)
Declining Technologies	Low efficiency furnaces and boilers (78-84%)	Low efficiency furnaces and boilers (78-84%)
Electric Cooling		
Ascendent Technologies	Mid-efficiency (COP 3.28) rooftop AC	Mid-efficiency (3.28 COP) rooftop AC; centrifugal (COP 7.0) and reciprocating (COP 3.2) chillers
Declining Technologies	More expensive mid-efficiency rooftop AC; wall and window AC	More expensive mid-efficiency rooftop AC, Reciprocating (COP 2.34) and centrifugal (COP 4.69) chillers
Electric Water Heating		
Ascendent Technologies	Solar and heat pump water heaters with 2011 costs	High efficiency (2.5 COP $176) solar water heater; heat pump water heater (2.3 COP $210)
Declining Technologies	Solar water heaters with 2010 costs and standard electric water heater	Standard electric water heater
Natural Gas Water Heating		
Ascendent Technologies	Standard gas water heater (COP 0.75-0.78)	High efficiency gas water heater with 2020 costs and efficiencies (COP 0.95)
Declining Technologies	High efficiency gas water heater with 2007 costs and efficiencies (COP 0.93)	High efficiency gas water heater with 2007 costs and efficiencies (COP 0.93)
Lighting		
Ascendent Technologies	F32T8 Super Fluorescents; LED 2011-2019 Typical for high tech	F32T8 Super Fluorescents; LED 2020-2029 Typical
Declining Technologies	F32T8 HE – standard, LED 2011-2019 Typical	26W Compact Fluorescent Lamps; F32T8 HE – standard; 70W HIR PAR-38

In other instances, the carbon tax enables consumers to take advantage of a class of technology that experiences both cost reductions and efficiency improvements. For example, in 2035, consumers who tended to purchase a high efficiency gas water heater with 2007 costs and efficiencies (COP 0.93) in the Reference case, tend to choose a slightly cheaper higher efficiency gas water heater (COP 0.95) in the Main Tax + High Tech scenario once it is available in 2020.

- Finally, carbon taxes can cause fuel switching. For example, there is a significant shift from electric space heating to gas space heating in the 2020-2035 timeframe. In the Main Tax + High Tech scenario, service demand for electric space heating decreases by 29 trillion Btu in 2035 relative to the Reference case, while natural gas space heating service demand gains 28 trillion Btu in that same year. As noted earlier, natural gas consumption decreases relative to the Reference case because the average coefficients of performance of gas space and water heating are higher in the Main Tax + High Tech scenario.

This last finding underscores the fact that the most important building technologies based on carbon dioxide emission reductions may not be the most cost-competitive high-efficiency technologies, but rather the technologies that can displace fossil fuels or enable a switch to less-intensive fossil fuels, as was also noted by Kyle et al. (2010). However, in the Kyle et al. (2010) study, the authors were referring to a switch from gas furnaces to electric heat pumps in the residential sector over the next century. In contrast, we've highlighted the possibility of a shift toward gas furnaces from electric heat pumps in the commercial sector over the next several decades. The recent identification and exploitation of large quantities of affordable shale gas in the U.S. in recent years may explain these otherwise inconsistent findings, underscoring once again that unanticipated technology and resource breakthroughs and surprises can quickly undermine the value of past energy forecasts.

Theoretically, the underlying technology and production cost improvements that enable these technology shifts can happen in three ways: through advances in R&D and general knowledge that result in improvements in technological performance; through economies of scale from increased size of production and operation; and lastly, through learning-by-doing or experience that is sometimes attributed to the cumulative experience of an entire industry. The High Tech portfolio of technologies is used to illustrate this technological progress. Without the impetus of the Main Tax, the High Tech case reduces the energy consumption of commercial buildings by 0.3 quads in 2035. When coupled with the carbon tax, it saves about 0.5 Q in 2035. Thus, the potential to consume less energy through better technology is amplified by a carbon tax.

The technological transformation of commercial buildings also requires the infusion of additional expenditures on energy-efficient equipment. Such investments pay back more rapidly to building owners in the Main Tax + High Tech case, since electricity, natural gas and other fossil fuels are more expensive. GT-NEMS generates estimated investment costs for individual technologies and vintages, and for major end-uses, including space heating, space cooling, water heating, refrigeration, cooking, ventilation, and lighting. These seven major end-uses account for the majority (50-60%) of energy consumption in commercial buildings between 2020 and 2035, both in the Reference case and in the Main Tax + High Tech scenario. The latter is estimated to stimulate an additional expenditure of 13 to 14% over this timeframe, rising slightly over time reflecting the increasing level of carbon taxation.

Geographic Variation

The effects of carbon taxes on commercial building energy efficiencies are geographically broad, based on estimates of their impacts across the nine U.S. Census divisions. The impact of the carbon tax on electricity rate, energy use in the commercial sector, and associated CO_2 emissions are shown in Figure 3. In 2020, energy savings range from 0.3% in the Pacific division to 12.4% in the Mountain division and 12.5% in the West South Central division. In the same year, reductions in CO_2 emissions range from 9% to 23%. For 2035, energy savings range from -1.1% in the Pacific division to 20.2% in the Mountain division, while reductions in CO_2 emissions range from 16% to 48%. As a general rule, the percentage energy savings is lower than the percentage reduction in CO_2 emissions, consistent with the shift to low-carbon energy resources that would be precipitated by a carbon tax. The amount of change varies over time and by region, but the direction is consistent, and the gap between energy savings and CO_2 grows over time.

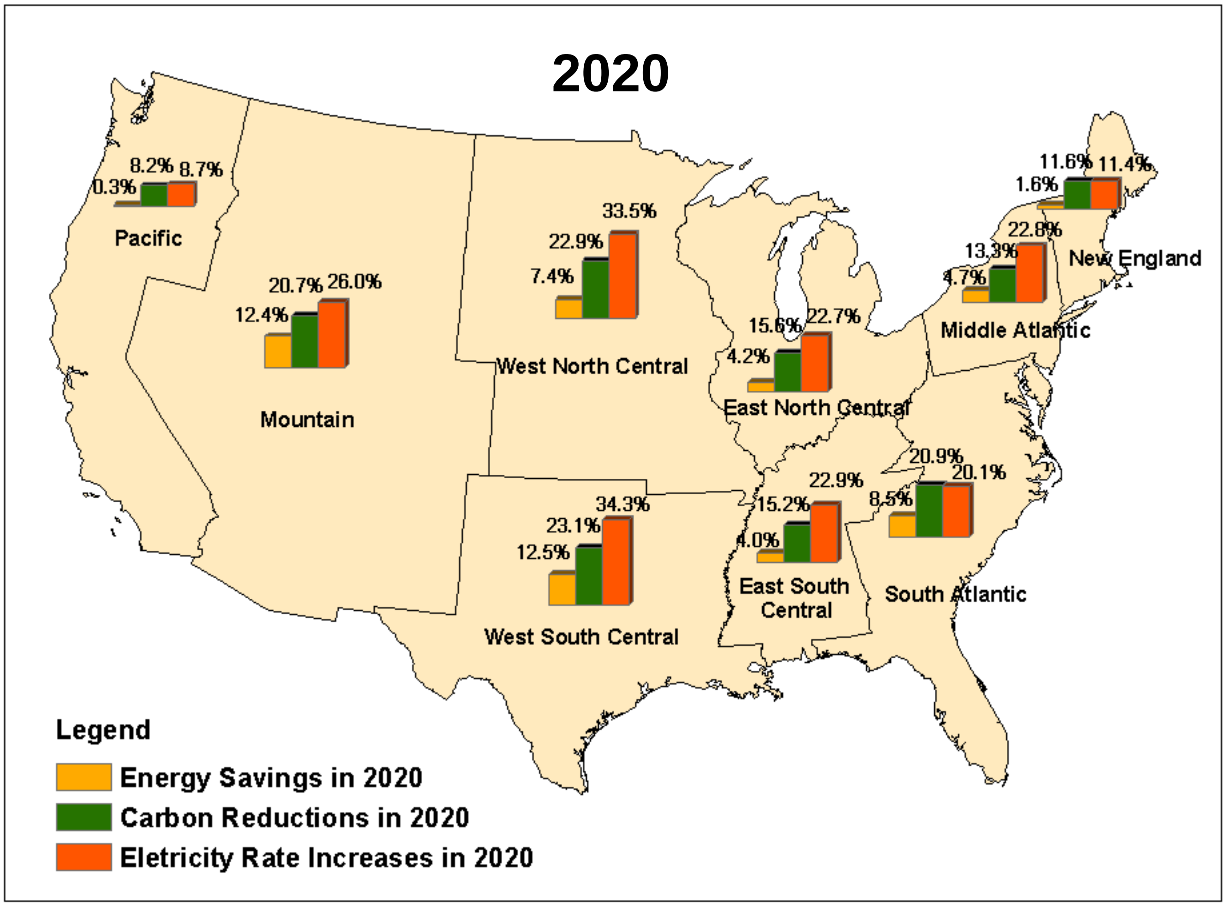
In the Pacific Census division, the Carbon Tax + High Tech scenario results in the lowest increase in electricity rates, reflecting the relatively low carbon intensity of energy sources in that region already. The increase in rates reduces carbon emissions but energy consumption is largely unaffected, suggesting that CO_2 emissions and energy consumption have been largely decoupled for this region. This also suggests that a carbon tax is unlikely to motivate much progress in reducing commercial energy consumption in the Pacific Census division.

In 2020, the South Atlantic and New England divisions are the two regions that reduce their CO_2 emissions proportionately more than their electricity prices increase. In 2035, this is also the situation in the Mountain division. These results suggest highly competitive low-carbon substitutes under a carbon tax regime.

The country's four central divisions and the Mountain division are estimated to experience the largest electricity price increases in the Main Tax + High Tech scenario. These are also the five divisions with the highest power sector carbon intensities. Thus, these regions appear to have conditions that make it difficult to rapidly move away from carbon-intensive energy sources, even with dramatic increases in electricity prices. At the same time, the carbon reductions increase significantly in these same divisions in 2020 and 2035, suggesting a rapid decarbonization. However, prices are still generally increasing faster than energy savings or carbon reductions.

The projections show that over time, the nine Census divisions generally develop the ability to rely on less carbon-intensive forms of electricity. However, the interactions between all the divisions are not obviously straightforward. For example, in 2020, the division with the highest percent increase in electricity rates (West North Central) is not the region with the highest carbon reductions (West South Central), and neither of those regions has the highest energy savings – which are experienced by the Mountain division. In 2035, the highest percent carbon reductions are estimated to occur in the Mountain division, which is second only to the West North Central division in the carbon intensity of its power sector. The West North Central division, in turn, experiences the highest rate increase and the highest energy savings. Altogether, the central divisions experience greater impacts from a carbon tax than the coastal divisions. Clearly the geographic consequences of imposing a carbon tax are complex and uneven.

Figure 3. Commercial Energy Consumption, Carbon Emissions and Electricity Rates by Census Division in 2020

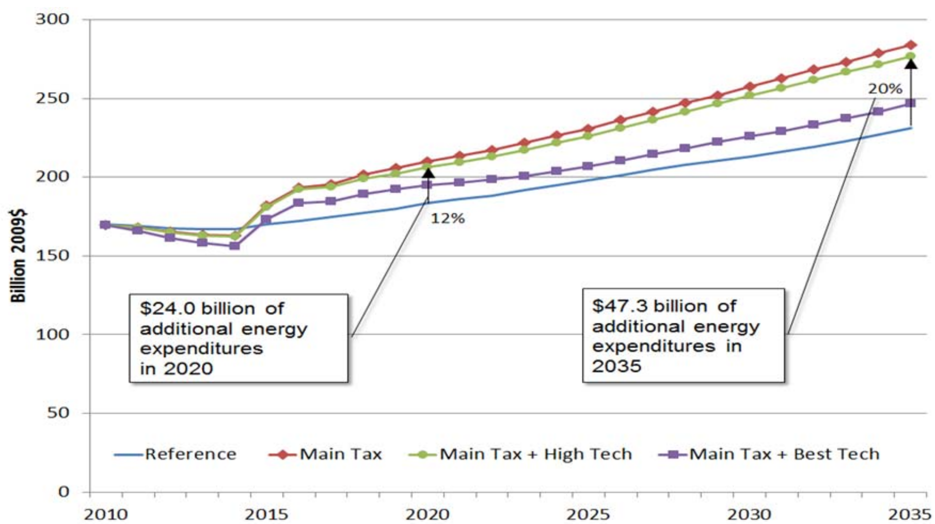


Impacts on Expenditures and GDP

The commercial sector energy expenditure in the Main + High Tech scenario increases by 20% in the 2035 relative to the reference scenario (Figure 4). Even though the energy consumption in the same scenario decreases by 15%, the energy price escalation outweighs the consumption reduction, thereby leading to higher sector-wide energy expenditures. A similar situation occurs in the Main Tax scenario. However, the Main Tax + Best Tech scenario is able to mitigate the expenditure increase with a higher level of consumption reductions even though it faces a similar energy price escalation.

GT-NEMS modeling suggests that improved technological options can significantly mitigate the cost of reducing commercial sector energy consumption and CO_2 emissions. The Main Tax scenario reduces energy consumption by 6% in 2020 and 10% in 2035 at a cost of 0.86% of GDP in 2020 and 0.32% of GDP in 2035. The Main Tax + High Tech scenario, on the other hand, produces a greater reduction in energy consumption (7% in 2020 and 12% in 2035) compared to the Reference case, for essentially the same GDP cost in 2020 and for a relatively small decline in GDP (0.32% vs 0.34%) in 2035. The impact on CO_2 emissions is even greater. Note that the GDP losses are for all sectors and not just for commercial buildings.

Figure 4. Commercial Sector Energy Expenditures (in Billions 2009-$): Main Tax Scenarios Versus Reference Case



U.S. economic activity is forecast to continue to grow in both the Reference case and in the carbon tax policy scenarios. The carbon tax scenarios would exert their largest impacts on GDP in the first five years of their implementation, with a cost of about 0.9 - 1.0% of GDP in 2020 with respect to the AEO 2011 Reference case (EIA, 2011). The estimated GDP penalties are much smaller in later years, declining to 0.3 to 0.4% of GDP in real terms by 2035. The cost of the Main Tax scenarios can be calibrated by considering the number of months that the nation's economy would have to operate in 2020 before GDP rises to the level it would have been in the absence of the carbon tax. As shown in Table 2, the Reference case GDP grows from $16.8 to $19.1 trillion between 2015 and 2020. In the Main Tax + High Tech case, GDP would rise to only $19.0 trillion in 2020, requiring the nation to wait four months before achieving a $19.1 trillion level of economic activity. By 2035, the delay is only 1.7 months.

Table 2. GDP Impact

Scenario	GDP (Billion 2009-$)	2015	2020	2035
Reference	GDP	16,847	19,138	28,217
Main Tax	GDP	16,791	18,974	28,126
	Change in GDP*	-0.33%	-0.86%	-0.32%
	Delay (month)**	1.7	4	1.6
Main Tax + High Tech	GDP	16,786	18,973	28,122
	Change in GDP *	-0.36%	-0.86%	-0.34%
	Delay (month)**	1.9	4	1.7
Main Tax + Best Tech	GDP	16,789	18,956	28,093
	Change in GDP *	-0.34%	-0.95%	-0.44%
	Delay (month)**	1.8	4.5	2.2

*"Change in GDP" is measured as the percentage change relative to the Reference case.
**"Delay" in GDP growth is defined as the number of months in a year required to make up the difference between GDP in the Reference case versus GDP in the carbon tax policy scenarios.

Carbon taxes offer the possibility of socially productive revenue recycling. The distribution of revenue from auctioned allowances or carbon taxes can, in principle, enhance policy efficiency or help reduce the regressive financial burden of emissions reduction efforts.

Conclusions

Our analysis of a Main Tax + High Tech scenario suggests that a carbon tax would reduce the consumption of energy by commercial buildings by 7% in 2020 and by 12% in 2035, compared with the Reference case forecast. Further, the GT-NEMS analysis indicates that a carbon tax would have significant impacts on the CO_2 emissions attributable to the commercial buildings sector. Because commercial buildings rely on electricity for a majority of their energy services, their carbon emissions are significantly reduced by the rapidly declining carbon intensity of the power sector, motivated by the carbon tax. In the Main Tax + High Tech case, commercial buildings would reduce their CO_2 emissions by 18% relative to the Reference case in 2020, and by 38% in 2035. In terms of energy intensity, the Main Tax + High Tech scenario delivers faster and deeper reductions in the commercial sector than in the economy broadly. Under the Main Tax + High Tech case, energy consumption (and CO_2 emissions) fall in all ten of the end-uses examined here.

The effects of carbon taxes on commercial building energy efficiencies would be technologically transformational and geographically broad. While energy expenditures would rise and more capital would be required for energy-efficiency upgrades, the avoided pollution would deliver more than $150 billion in cumulative human health and other benefits through 2035, and the reduced CO_2 emissions would avoid damages worth more than $100 billion over the same period.

While the Main Tax + High Tech scenario would shift commercial buildings toward greater energy efficiency, they would likely not deliver the magnitude of energy savings envisioned by the Better Buildings Initiative. In addition, the impacts are estimated to fall short of meeting the Waxman-Markey and Copenhagen carbon reduction goals of 17% below 2005 levels in 2020. Complementary policy measures will be needed to address financial, regulatory, and information barriers to investments in energy-efficient technologies in the commercial sector, if these goals are to be met.

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