Climate and Transportation Solutions:

Findings from the 2009 Asilomar Conference on Transportation and Energy Policy

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Published by
Institute of Transportation Studies
University of California, Davis
One Shields Avenue, Davis, California 95616

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Chapter 3:

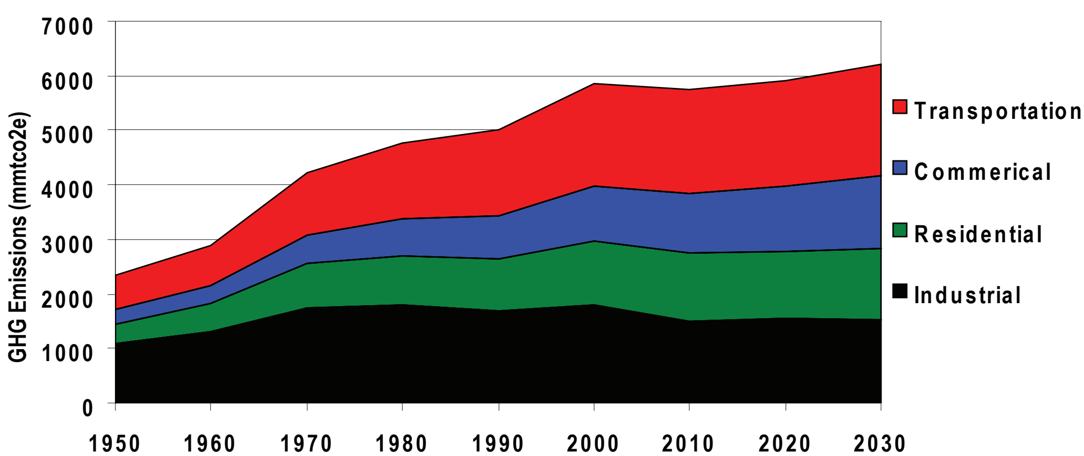
U.S. Greenhouse Gas Emissions in the Transportation Sector

by John Conti, Nicholas Chase, and John Maples

Transportation is the single largest emitter of greenhouse gases (GHG) in the United States (U.S.) among the four end use sectors, which also include commercial, residential, and industrial end use sectors, with emissions associated with electricity generation distributed to the sectors where electricity is consumed. According to data collected by the U.S. Energy Information Administration (EIA) and projected through its National Energy Modeling System (NEMS), GHG emissions in the transportation sector grew from 630 million metric tons of carbon dioxide equivalent (mmtCO_{2e}) in 1950, representing 27 percent of the total U.S. emissions, to 1,882 mmtCO_{2e} in 2009, representing 33 percent of the U.S. total (EIA 2008).

GHG emissions in the transportation sector in the U.S. more than tripled between 1950 and 2009, but are projected to remain relatively flat between 2010 and 2030. Figure 3-1 shows the trends in GHG emissions

Figure 3-1: Historical and projected U.S. GHG emissions by end use sector, 1950-2030



Source: EIA National Energy Modeling System Emissions Data

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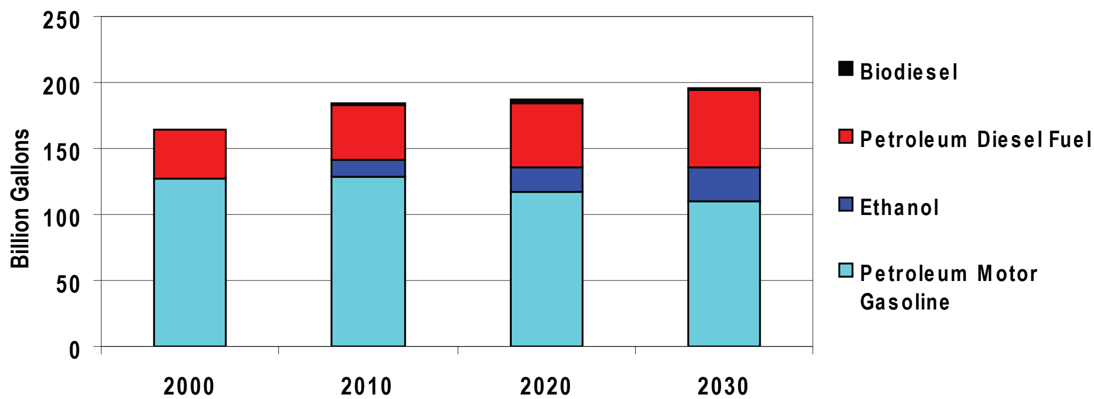
by energy sector from 1950 to projected emissions in 2030. In the 1980s, transportation overtook the industrial sector to become the largest emitting end use sector, driven by increased personal mobility as rising income and low fuel prices stimulated motorization and the suburbanization during the era after the end of World War II in what became the greatest migration in American history.

The EIA *Annual Energy Outlook 2009* updated reference case projects that the transportation sector's GHG emissions will increase from 1,905 mmtCO_{2e} in 2010 to 2,045 mmtCO_{2e} by 2030 (EIA 2009a). Transportation's overall share of emissions is projected to remain at 33 percent throughout the forecast period, continuing its distinction as the largest source of GHG emissions among U.S. end use sectors.

Total liquid fuel consumption in transportation, including petroleum motor gasoline and diesel, ethanol, and biodiesel, is projected to grow from 164 billion gallons in 2000 to 196 billion gallons by 2030, as shown in Figure 3-2. Ethanol and biodiesel consumption is projected to grow from nearly zero in 2000 to 28 billion gallons in 2030, with ethanol accounting for 26 billion gallons of the increase. Because emissions from ethanol feedstock production and conversion are counted in the industrial end use sector, GHG emissions from liquid fuel consumption reported for the transportation sector will remain almost flat between 2000 and 2030. The sidebar discusses the accounting of GHG emissions from biofuel production and use in the NEMS.

Figure 3-2: Total liquid fuel consumption in transportation



Source: EIA National Energy Modeling System Emissions Data

GHG Emissions in Transportation Modes

Between the years 1950 and 2000, the U.S. economy underwent a rapid expansion, growing from $293.7 billion in 1950 to $9.52 trillion by 2000, corresponding to a real disposable personal income increase from $1,401 billion in 1950 to $8,161 billion by 2000.

This quintupling of real personal income drove a corresponding increase in the amount of vehicle miles traveled. While these trends affected primarily the light duty vehicle (LDV) sector, similar trends occurred in other transportation sectors as the U.S. economy grew and wealth increased. Consumer demand increased for a vast array of goods, which required the movement of large quantities of materials and industrial output and increased the emissions from heavy duty vehicles. Similarly, the air travel mode became a major form of travel as wealthier consumers demanded more air travel.

Figure 3-3 shows the growth in transportation GHG emissions by transport mode from 1970 to 2005, followed by a leveling off predicted to continue through 2030. Almost all the GHG emissions that resulted from transportation demand over the past few decades have been derived from the combustion of petroleum products.

Since 2005, GHG emissions from the transportation sector have remained relatively flat and are projected to remain relatively flat through 2030, rising from 1,872 mmtCO_{2e} in 2000 to 1,904 mmtCO_{2e} in 2010, and 1,929 mmtCO_{2e} in 2020, before moving slightly upward to 2,045 mmtCO_{2e} in 2030. Petroleum products will remain the overwhelming source of GHG emissions in the transportation sector, but biofuels will also begin to play an important role. Because of the accounting method used by the EIA, the growing use of ethanol and the less significant growth in the use of biodiesel across the projection period explain in large part, but not entirely, why GHG emissions in transportation have remained and are projected to remain relatively flat between 2000 and 2030.

Light duty vehicles (LDVs) represent the single largest source of GHG emissions in the transportation sector by a wide margin, accounting for around 59 percent of total transportation emissions today. Throughout the EIA projection period, LDV GHG emissions will continue to represent the single largest emission source, although emissions are projected to decline four percent as a result of higher fuel economy standards and the increasing use of biofuels. Heavy duty truck GHG emissions are projected to increase 31 percent, growing from 17 percent of total transportation GHG emissions in 2009 to 23 percent by 2030, furthering the heavy duty truck mode's place as the second largest overall GHG emitter in the transportation sector. GHG emissions from air travel are projected to increase 36 percent, the highest rate of increase in the forecast. Marine and rail are projected to grow, but remain relatively minor sources of energy use and GHG emissions in the U.S.

Light Duty Vehicle GHG Emissions

In 2009, LDVs, vehicles with a gross vehicle weight rating up to 10,000 pounds accounted for 1,104 mmtCO_{2e} out of a total of 1,882 mmtCO_{2e}. Emissions are projected to decline to 1,062 mmtCO_{2e} in 2030, a decrease of 42 mmtCO_{2e}. This decline will lower the LDV mode's overall share of transportation GHG emissions from 59 percent to 54 percent in 2030. Biofuels consumption in LDVs is projected to increase to 28 billion gallons by 2030, which will offset almost all of the growth in liquid fuel demand in the LDV fleet.

Higher proposed fuel economy standards mandated by the Energy Independence and Security Act of 2007, which require new LDVs to reach a fuel economy of 35 miles per gallon (mpg) by 2020, also contribute to the decline in projected GHG emissions (EISA 2007). As new vehicles enter the LDV fleet, the stock average fuel economy for those vehicles is projected to increase from 20.5 mpg in 2009 to 24.6 mpg in 2020 and 28.9 mpg in 2030. While the stock average fuel economy is projected to increase, the impact on emissions is forecast to be strongest in the early part of the projection period because of the continuing growth in overall LDV miles traveled (VMT). Total light duty VMT is forecast to increase from 2,856 billion miles in 2010 to 3,221 billion miles in 2020 and 3,936 billion miles in 2030. Between 2010 and 2020, the stock average fuel economy increases at a rate of 20 percent, while VMT increases at a rate of only 13 percent; thus, GHG emissions are driven downward. Combined with the increasing use of ethanol, emissions decline between 2010 and 2020.

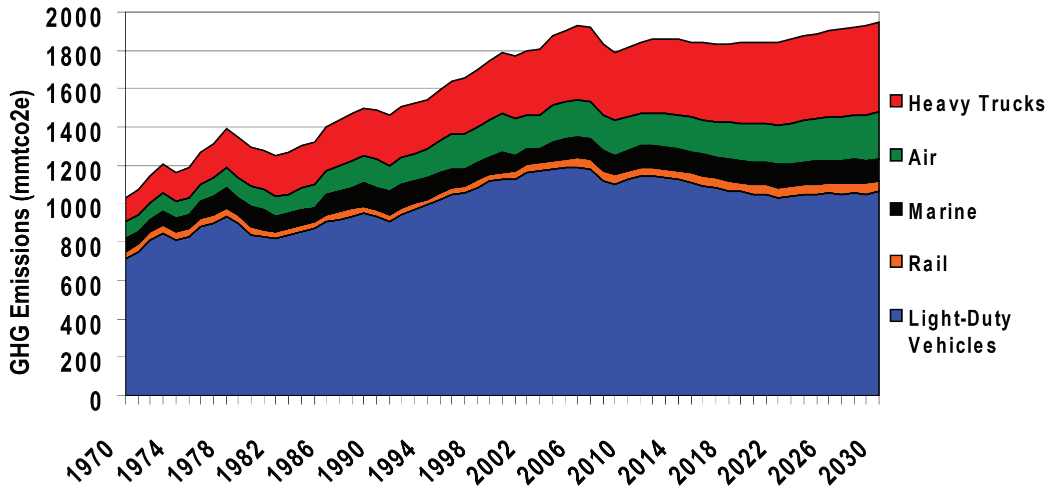
GHG Emissions and Biofuels

Consumption of biofuels produces varying amounts of GHG emissions, depending on the accounting for and allocation of life cycle emissions, including feedstocks used, fuels consumed, and land use emissions. In the NEMS, GHG emissions from biofuels, including both ethanol and biodiesel, are calculated using a field-to-tailpipe accounting method, with land use emissions currently excluded and emissions distributed across various energy sectors. Due to this accounting, full GHG emissions are not accounted for in the transportation end use sector.

In transportation, vehicle GHG emissions from biofuels are assumed to be zero as they are completely offset by the growing of the feedstock. Biofuel process emissions are counted in the industrial end use sector based on the energy used in agriculture for the production of crops and in the production process of turning the biofuel feedstock into a transportation fuel. GHG effects of direct or indirect changes in land use are not tracked in the NEMS.

The fact that GHG emissions from biofuels feedstock production and conversion processes, excluding changes in land use, are accounted for in the NEMS outside of the transportation end use sector has significant implications for projecting emissions for transportation because of the projected growth of biofuel used as a liquid transportation fuel.

Figure 3-3: GHG emissions by transport mode, 1970-2030



Source: DOE 2009; EIA 2008

Between 2020 and 2030, stock average fuel economy increases at a rate of only 17 percent, while VMT grows at a rate of 22 percent, which, when combined with a growing use of biofuels, still leaves total LDV GHG emissions lower in 2030 than 2010, but higher than 2020. If, beyond 2030, VMT continues to grow and biofuels use and fuel economy do not continue to increase, LDV GHG emissions will begin to increase again.

Heavy Duty Vehicle GHG Emissions

While LDV GHG emissions are projected to decline, heavy duty truck GHG emissions are projected to increase 31 percent between 2009 and 2030, representing the largest absolute increase and the second largest percentage increase in GHG emissions in the transportation sector during the forecast period. Heavy duty truck GHG emissions are projected to grow from 17 percent of total transportation GHG emissions in 2009 to 23 percent by 2030, continuing to place heavy duty trucks as the second largest overall GHG emitter in the transportation sector.

The driving force behind this increase is the growth in heavy duty VMT from 226 billion miles in 2009 to 347 billion miles in 2030, which is itself driven by a corresponding growth in industrial output from $4,927 billion 2000 dollars to $7,391 billion by 2030. While heavy duty vehicle fuel economy is projected to increase, the increase is not significant enough to offset the growth in VMT.

Air GHG Emissions

GHG emissions from air travel are the third largest source of emissions in the transportation sector and represent the fastest growing mode. Aircraft accounted for 179 mmtCO_{2e} of emissions in 2009, 10 percent of total transportation emissions. GHG emissions in the air mode are projected to increase 65 mmtCO_{2e} by 2030, the second largest absolute increase among transportation modes. By 2020 aircraft emissions reach 200 mmtCO_{2e} and by 2030 reach 244 mmtCO_{2e}, or 12 percent of transportation total.

GHG emissions from air transportation increase because aircraft travel demand as measured in air seat miles available is predicted to increase from 995 billion miles in 2009 to 1,465 billion miles in 2030, a growth of 47 percent. Air travel demand stems from rising real disposable personal income per capita, which increases from $29,157 (in 2000 dollars) in 2009 to $42,741 by 2030, also a growth of 47 percent. Aircraft fuel economy measured in aircraft seat miles per gallon of jet fuel is projected to increase 15 percent from 63.6 to 73.4, partially offsetting increased aircraft travel demand.

Marine and Rail GHG Emissions

The remaining non-highway transportation modes also are forecast to experience growth in GHG emissions. Marine and rail are the fourth and fifth largest sources of GHG emissions in the transportation sector, respectively. In 2009, marine traffic accounted for five percent of total transportation emissions, while rail accounted for two percent of total transportation emissions.

Marine emissions are projected to increase from 102 $mmtCO_{2e}$ in 2009 to 118 $mmtCO_{2e}$ by 2030, or six percent of total transportation emissions after a 16 percent growth. Rail emissions are forecast to grow from 46 $mmtCO_{2e}$ in 2009 to 56 $mmtCO_{2e}$ in 2030, remaining around three percent of total emissions despite a 22 percent growth. Marine and rail emissions are driven by an increase in ton miles traveled in each mode while fuel efficiency in both is projected to remain relatively constant in terms of ton miles per Btu.

Impacts of ACESA

GHG emissions are unregulated in the United States, but continue to garner significant attention because of concerns about anthropogenic climate change. Since transportation accounts for one-third of total U.S. GHG emissions by end use, great focus and attention has been devoted to developing policies that could substantially reduce its emissions. One way to reduce GHG emissions that has drawn the support of many U.S. lawmakers is through a cap-and-trade program. This system functions by using market-based methods to reduce GHG emissions by essentially making it more costly to emit GHGs. A cap-and-trade system sets an overall level of allowable GHG emissions for the entire economy, minus exempted sources. Allowable emissions are then allocated to various emissions sources that are required to maintain emissions at levels below the caps.

Compliance is enforced through a requirement for entities subject to the cap to report GHG emission allowances, which are bankable, sufficient to cover their emissions. For those unable to do so, allowances can be purchased from other owners of emissions sources that successfully reduced emissions below the amount they were allotted. This effectively places a price on GHG emissions and creates a market price on allowances as an incremental cost to emitting GHGs. A final, but critical, element of a cap-and-trade system is that the GHG emission caps are reduced over time with the expectation that the market price to emit a given unit of GHG emissions will increase and encourage efforts to reduce emissions.

On June 26, 2009, the U.S. House of Representatives passed H.R. 2454, the American Clean Energy and Security Act of 2009 (ACESA), a complex bill that uses a cap-and-trade market-based mechanism to reduce the emission of GHG emissions, along with efficiency programs and other economic incentives (ACESA, 2009). The Title III cap-and-trade program for GHG emissions, which covers roughly 84 percent of total U.S. GHG emissions by 2016, is in many respects the centerpiece of the bill. The program subjects covered emissions to a cap that declines steadily between 2012 and 2050. The cap requires a 17 percent reduction in covered emissions by 2020 and an 83 percent reduction by 2050, relative to a 2005 baseline with targets that decline steadily for intermediate years.

EIA Analysis of ACESA

The EIA analyzed ACESA by considering the energy-related provisions in the proposed legislation that can be analyzed using the National Energy Modeling System (EIA 2009b). The starting point for the analysis was the updated reference case of the *Annual Energy Outlook 2009* (EIA 2009a), which includes the American Recovery and Reinvestment Act (ARRA 2009) and other updates capturing recent changes in the U.S. economy. While this analysis is as comprehensive as possible, it does not address all provisions of ACESA, such as the authority provided to establish efficiency standards for transportation equipment other than LDVs and the effects of increased investment in energy research and development. Thus, results are presented with the important caveat that the lone effect on the transportation sector from ACESA analyzed by the EIA is the impact of a cap-and-trade system on fuel prices.

Furthermore, the analysis of ACESA separates demand sectors by transportation, industrial, buildings, and electric power for analysis. This differs from the method used in the first section of this chapter. The analysis in the first section divided emissions between industrial, commercial, residential, and transportation, with electricity usage attributed to the various end users. For its analysis of H.R. 2454, GHG emissions from electric power generation were aggregated and compared to emissions from the transportation, residential and commercial buildings, and industry sectors.

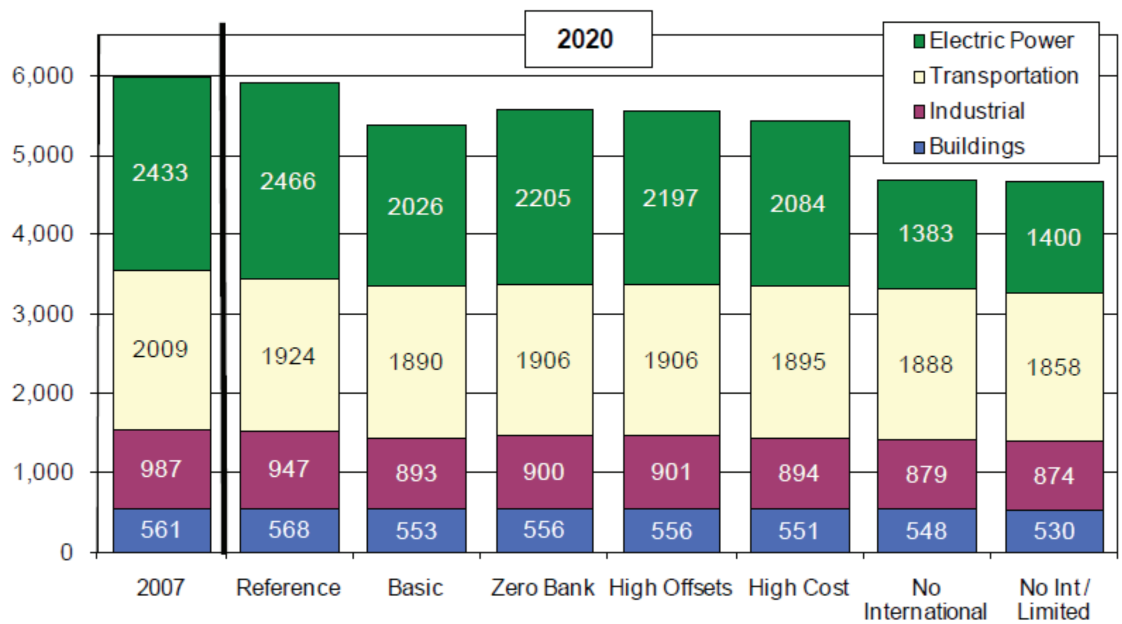
Allowance prices in the ACESA cases varied from between \$20 and \$93 per metric ton of CO_{2eq} in 2020 to between \$41 and \$191 per metric ton of CO_{2eq} in 2030, depending on the various allowance scenarios evaluated in the report. The EIA prepared a range of analysis cases for this report. The six main scenarios focus on two key areas of uncertainty--namely, the role of offsets and the energy system and economic impacts of ACESA on the timing, cost, and public acceptance of low carbon and no carbon technologies. The ACESA basic case projects a price of \$32 per metric ton in 2020 and \$65 in 2030.

Analysis Results

Figure 3-4 summarizes the EIA analysis of GHG emissions in 2020 from all energy sectors under each of the main scenarios examined. According to the EIA analysis, implementation of ACESA will reduce carbon dioxide (CO_2) emissions between 338 and 1,243 million metric tons (mmt) in 2020 depending on the various allowance cases. Emissions fall from 5,905 mmt in the updated reference case to between 4,662 and 5,567 mmt, a decline of between 6 and 21 percent. Emissions projected for 2030 under each scenario are summarized in Figure 3-5. GHG emissions decline from 6,207 mmt in the updated reference case to between 3,633 and 5,293 mmt in the ACESA scenarios, a drop of between 13 and 41 percent.

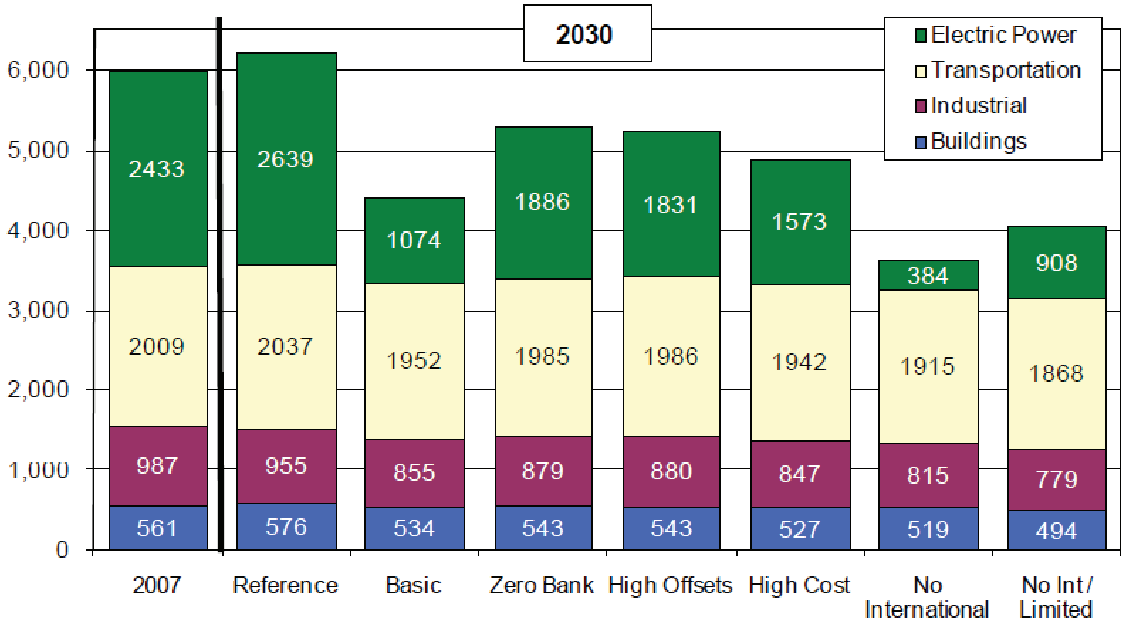
Transportation is projected to account for relatively little of the total GHG emission reductions due to ACESA. In 2020, transportation CO_2 emissions decline only between 18 and 66 mmt across cases, from 1,924 mmt to

Figure 3-4: Energy related CO_2 emissions by sector in ACESA main cases, 2020 (mmt CO_2)



Source: National Energy Modeling System Data

Figure 3-5: Energy related CO_2 emissions by sector in ACESA main cases, 2030 (mmt)



Source: National Energy Modeling System Data

between 1,858 and 1,906 mmt, a reduction of only one to three percent. By 2030, transportation emissions will decrease from 2,037 mmt to between 1,915 and 1,985 mmt, a reduction of just 2.5 to 6 percent.

Since emissions from electric power are not included as transportation emissions in the EIA analysis of H.R. 2454, electricity consumption by electric vehicles or plug-in hybrid electric vehicles, while counted towards transportation emissions in the first section of this chapter, are now attributed to the electric power sector. Transportation GHG emissions associated with electricity are predicted to be about 5 $mmtCO_{2e}$ in 2020 and 8 $mmtCO_{2e}$ in 2030. This explains the difference in total transportation emissions between the H.R. 2454 analysis updated reference case and the updated reference case of the *Annual Energy Outlook 2009*.

As a result of the relatively small decline in transportation GHG emissions as a result of ACESA, transportation's overall share of energy-related end-use emissions increases from 33 percent in 2020 in the updated reference case to between 34 and 40 percent in the ACESA scenarios and from 33 percent in 2030 to between 38 and 53 percent.

The EIA projects that the vast majority of GHG emission reductions will take place in other sectors affected by ACESA. Specifically, between 80 and 88 percent of reductions in energy-related emissions by 2030 are expected to occur in electric power generation, reflecting both a change in the electric generation mix and reduction in electricity consumption in the residential, commercial, and industrial end use sectors. Reductions are primarily achieved by reducing the role of conventional coal-fired generation, which in 2007 provided 50 percent of total U.S. generation, and increasing the use of no carbon or low carbon generation technologies that either exist today, in the case of renewable resources and nuclear power, or are under development, for example, carbon capture and sequestration from coal burning.

The relatively small changes in transportation are driven by the modest changes in fuel prices. For example, gasoline price is expected to increase just $0.12 to $0.67 above the $3.62 per gallon projected in the updated EIA reference case in 2020 and between $0.20 and $1.28 above the $3.82 per gallon price in 2030.

EIA's analysis of ACESA also includes a sensitivity case that incorporates President Obama's plan for tougher CAFE standards. The new CAFE standards require passenger cars to reach a fleet average of 39 mpg and light trucks to reach a fleet average of 30 mpg in model year 2016. In the sensitivity case, these new fuel economy standards are slightly exceeded for model year 2016, reaching 39.3 mpg for passenger cars, 30.4 mpg for light trucks, and a combined 34.8 mpg given the mix of cars and trucks projected for that year, compared to the 38.0, 27.9, and 32.9 miles per gallon projected in the *Annual Energy Outlook 2009* updated reference case, respectively. The difference in achieved fuel economy for light-duty vehicles narrows subsequently, with fuel economy reaching 36.4 mpg in 2020 in the CAFE sensitivity case compared to 35.6 mpg in the reference case and 38.7 mpg in 2030 versus 38.1 mpg. The revised standards do not start until 2012, as fuel economy standards for model year 2011 have already been promulgated by the National Highway Traffic Safety Administration. Standards are assumed to remain the same after model year 2016.

Light-duty vehicle GHG emissions in the CAFE sensitivity case decline from 1036.5 $mmtCO_{2e}$ in 2016 to 982.5 $mmtCO_{2e}$ in 2020 and 952.2 $mmtCO_{2e}$ in 2030, compared to 1055.5 $mmtCO_{2e}$, 1011.8 $mmtCO_{2e}$, and 1021.3 $mmtCO_{2e}$ in the updated reference case, respectively. As a percent, the proposed CAFE standards reduce LDV emissions by 2 percent in 2016, 3 percent in 2020, and 7 percent in 2030 compared to the reference case. As a total percent of transportation, the new CAFE standards reduce GHG emissions by 1.5 percent in 2016, 2.2 percent in 2020, and 5 percent in 2030.

Conclusions

The EIA has concluded that a cap-and-trade system that effectively places a price on GHG emissions will produce relatively little reduction in GHG emissions from the transportation sector. This implies that, for a given price on GHG emissions, the transportation sector is not the most cost effective sector to reduce emissions. Also, recently proposed CAFE standards offer reductions in transportation GHG emissions. However, even these reductions are moderate and would require much higher standards to more significantly reduce emissions relative to the updated reference case.

This implies that the transportation sector does not initially offer many opportunities for emission reduction that are as cost effective as those available in other sectors, such as changes in the electricity generation mix. The transportation sector is, however, the largest end-use GHG emitter, and the second largest demand-based source of emissions if electric power is counted separately. Thus, efforts to significantly reduce U.S. GHG emissions will eventually need to address transportation sector emissions.

While a price on carbon does not yield significant reductions in transportation emissions, at least four major proposals have been put forth and advocated as ways to reduce GHG emissions in transportation:

- Increasing vehicle fuel economy standards
- Using low carbon fuel alternatives
- Reducing vehicle miles traveled by mode switching from LDVs into rail and from heavy truck freight into rail and marine freight
- Changing land use patterns

There are many challenges and uncertainties facing the implementation of any of these proposals, but they merit careful analysis and consideration, if energy security considerations, equity concerns, or the need to prepare for deeper GHG emissions reductions in the future are deemed to require greater near-term reductions in fossil fuel use in the transportation sector than the ACESA market-based cap-and-trade system is expected to provide.

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