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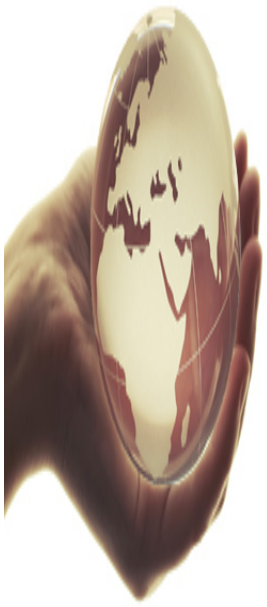

Key Investments in Greenhouse Gas Mitigation Technologies from 2000 Through 2012 by Energy Firms, Other Industry and the Federal Government

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Undertaken for API

Preface

Glossary of Terms (for extended discussion see page 25)

Technology Categories

Fuel substitution technologies include liquefied natural gas (LNG), shale gas, nuclear, and landfill gas.

*End-us*e technologies include efficiency improvements, such as cogeneration (CHP), improved lighting, and carbon capture and storage (CCS).

Non-hydrocarbon technologies include any energy form that is not a hydrocarbon energy source, such as wind, solar and biomass.

Enabling technologies are necessary and often basic technologies that allow other technologies' use and include various consortia that are researching and developing a wide variety of technologies, and include several university programs.

Alternative Fuel Vehicles and Advanced Technology Vehicles use both petroleum and nonpetroleum based fuels (or mixtures) or fuel-cell technologies.

Biomass uses plant materials, animal fats and wastes, or woody material to produce energy.

Biorefineries produce a broad slate of products from plant materials and/or animal fats.

Biodiesel is an increasingly important sub-group of this technology. Biodiesel is produced by chemically altering plant oils (e.g., soybean oil) and/or animal fats into diesel fuel substitutes. The term generally refers only to diesel substitutes produced from vegetable oils and/or animal fats. However, this study includes other bio-derivatives including those produced as refinery products, such as certain higher alcohols and alkanes.

Carbon Capture and Storage (CCS) is the capture and long term storage of carbon dioxide emissions from combustion processes.

Cogeneration, or *combined heat and power* (CHP), is the simultaneous production of both electricity and thermal energy (steam, hot water, hot air).

Ethanol is a liquid fuel, currently produced by the fermentation of various sugars, primarily from corn and sugar cane. Sugar cane is not a significant source in the North American market. Technologies to produce ethanol from cellulose have just begun commercial application.

Gasification is a thermal process for converting solid materials (e.g. biomass, coal or petroleum coke) into a synthetic gas. The gas may be used directly, or converted to hydrogen or liquid fuels.

Gas Flaring occurs when crude oil is extracted from the earth and natural gas associated with the oil is produced to the surface as well. In areas of the world lacking natural gas infrastructure and markets, this associated gas is usually flared (burned) or sometimes vented (emitted as un-burnt gas).

Liquefied natural gas (LNG) is natural gas that has been super-cooled to a liquid for transport. This dramatically reduces the volume for cost-effective transport over longer distances.

Landfill gas (LFG) is methane that is produced anaerobically in landfills from the decomposition of waste material.

SF6 is sulfur hexafluoride. It is used in the electrical industry as a dielectric and within the magnesium production industry.

Fluorocarbons and halogenated fluorocarbons are various chemicals used as either refrigerants or industrial cleaning agents. Several of them are greenhouse gases, while others can deplete ozone. Industry continues to develop substitutes for those fluorocarbons.

Nitrous Oxides (N_2O) are produced by both biogenic and anthropogenic sources. Primary anthropogenic sources of N_2O are agricultural practices related to the use of fertilizer. Nitrous oxide is also produced naturally from a wide variety of biological sources in soil and water, particularly microbial action in wet tropical forests.

Shale Gas is an important source of expanded supply of natural gas in the U.S., typically produced through a well tested process known as hydraulic fracturing. As a greenhouse gas emission reduction technology, shale gas increases the supply of natural gas to the North American market that may substitute for coal, and to a lesser extent for petroleum fuels. The potential for greenhouse gas mitigation is determined, however, by the amount of gas-on-gas substitution versus gas-on-coal.

A *Disruptive Technology* is a new technological innovation, product, or service that overturns the existing dominant technology in the market, despite the fact that the disruptive technology is radically different from the leading technology and requires fundamental infrastructure and support changes.

"Global Warming Potential" of Greenhouse Gases

Each greenhouse gas has been defined by the U.S. Environmental Protection Agency as having a different "global warming potential" that is measured relative to carbon dioxide (CO_2). The gases that are included within this analysis have been reported to have the following global warming potentials[1]:

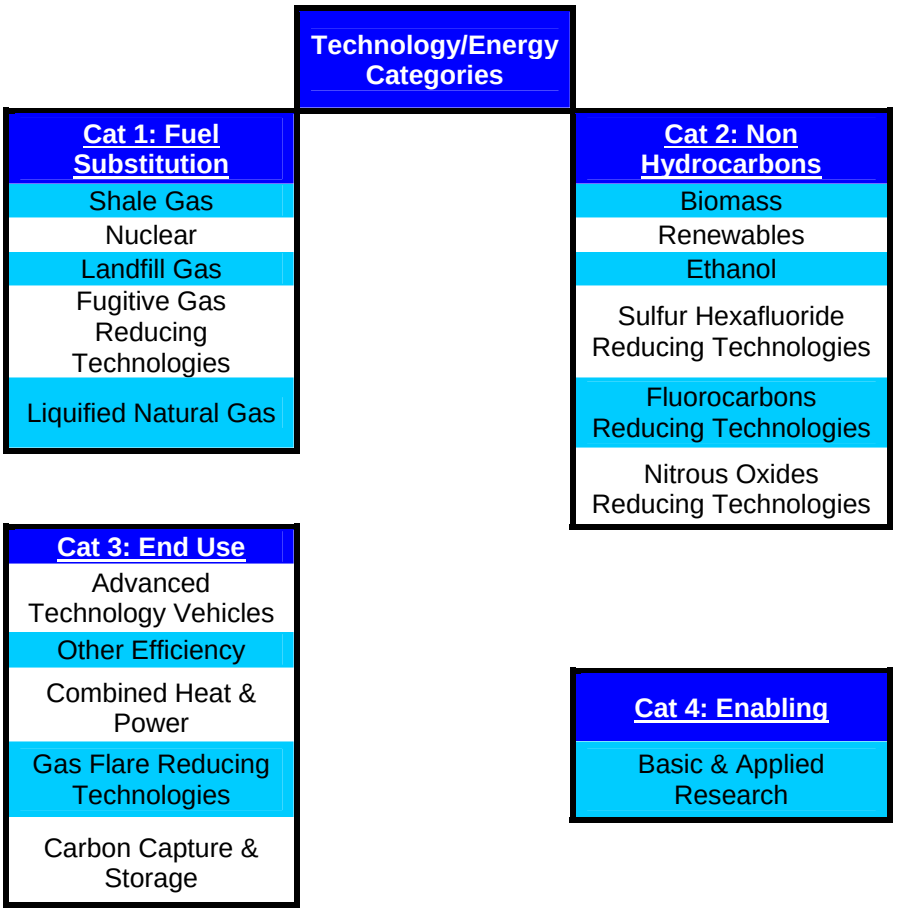
- Carbon Dioxide (CO2) 1
- Methane (CH_4) 25
- Nitrous Oxide (N_2O) 298
- Halogenated Fluorocarbons 1030-14,800*
- Fluorocarbons 7,400-10,300*
- Sulfur Hexafluoride (SF_6) 22,800

*Actual value depends on specific chemical within a class

[1] U.S. Environmental Protection Agency, Inventory Of U.S. Greenhouse Gas Emissions And Sinks: 1990-2011 (April 2013); http://www.epa.gov/climatechange/emissions/usinventoryreport.html GWP numbers from IPCC's Fourth Scientific Assessment Report.

Figure P-1

Categorization of GHG Mitigating Technologies



Executive Summary

This report provides estimates of the investments made from 2000 through 2012 in various greenhouse gas emission reduction technologies. Estimates are provided for the oil and gas industry, other private sector companies, and the Federal Government.

North American investments in GHG mitigating technologies are estimated to have totaled $336.3 billion (2010 dollars) between 2000 and 2012.[2] Figure ES-1 summarizes these greenhouse gas mitigation investments by investor type and by technology category. Over the 2000 – 2012 period, the U.S. based oil and natural gas industry invested an estimated $165.4 billion in GHG mitigating technologies including shale gas, or $81.0 billion without shale gas investments, other U.S. based private industries invested an estimated $91.2 billion, and the Federal Government invested an estimated $79.7 billion.

Major investments by the oil and natural gas industry included shale gas (especially over the 2009-12 period), efficiency improvements including combined heat and power, and advanced technology for vehicles. Investments in wind, biofuels and solar were also made. Other private industries' major investments included advanced technology vehicles, efficiency improvements in electricity generation, biofuels, wind and solar. The Federal Government has spread investment across all technology categories with major investments in energy efficient lighting, wind, solar, biofuels and basic research. Significant investments in renewables and efficiency were made between 2009 and 2012 as part of the American Recovery and Reinvestment Act of 2009 (ARRA). In earlier periods, federal spending was more heavily focused on early-stage development investments, particularly at the basic research stage. Now it includes later stage and commercial plants, such as the Section 1603 direct grants to wind energy facilities in lieu of tax credits.

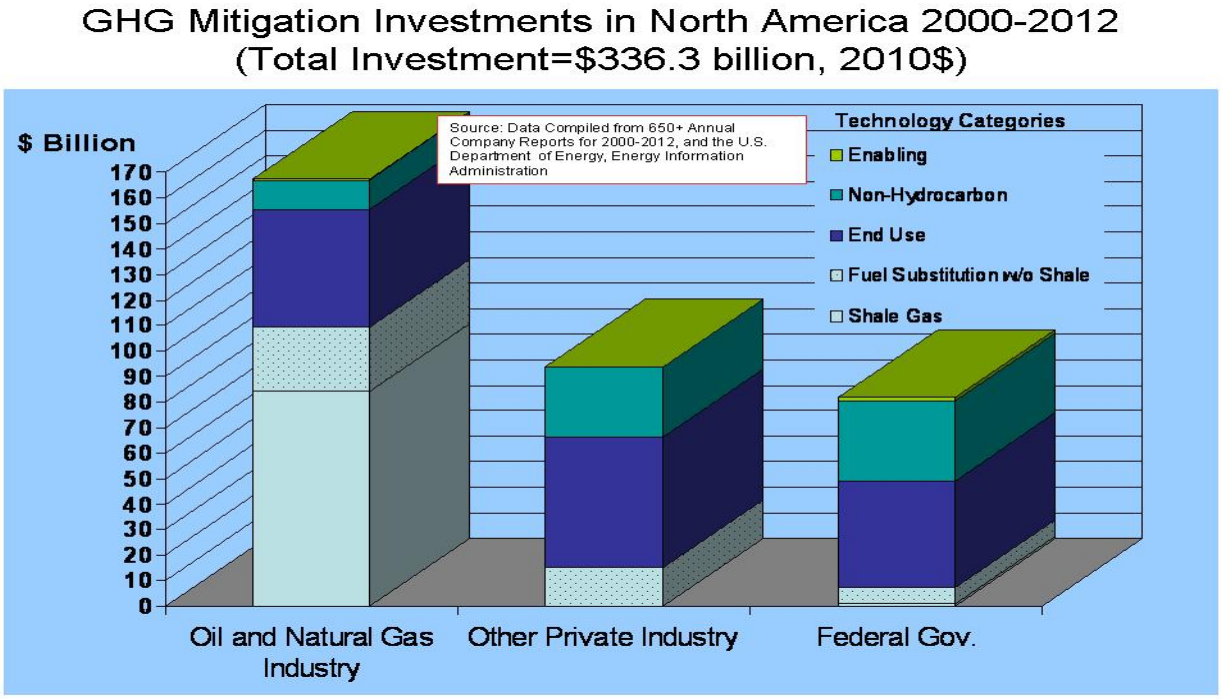
Emission Reductions

The EIA[3] has reported that energy-related greenhouse gas emissions in the United States declined in 2011 by 2.9 percent compared to 2010 and an additional 2.1 percent in 2012 compared to 2010. In 2012 emissions were 705 million metric tons (13 percent) below the 2005 level. Energy-related carbon dioxide emissions have declined in the United States in four out of the last six years.

[2] "North American market" is used herein to include Canada and the U.S. Percentages may not add to 100% due to rounding. All figures are provided in 2010 dollars.

[3] Noted trends and statistics in this paragraph are from Energy Information Administration, U.S. Energy Related Carbon Dioxide Emissions, 2011, Release Date: August 2012 and http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2013&subject=0-AEO2013&table=17-AEO2013&region=1-0&cases=ref2013-d102312a

Figure ES-1



In 2012 GDP grew by 3.0 percent, and emissions increased by 3.9 percent, largely as a result of a rebound in coal use for power generation and continued economic recovery. The 2012 emission intensity degraded slightly, about 0.9 percent, compared to 2011.[4] The decrease in U.S. GHG emissions in 2011 resulted primarily from mild weather and a declining price of natural gas that caused fuel switching away from coal to natural gas in the electric power sector. This decrease in emissions was also driven in part by Federal EPA regulations that resulted in switching from coal to gas in electricity generation. In 2011, GDP grew by 1.8 percent, but emissions decreased by 2.4 percent (136 million metric tons). This indicates that the carbon intensity of the economy improved by about 4.2 percent from 2010 to 2011. Since 1990, GHG emissions in the United States have grown much more slowly than GDP; in 2007 emissions reached a peak of about 20 percent greater than 1990, while 2012 GHG emissions have fallen, and are only about 12 percent more than in 1990. GDP has increased by 63 percent over that same time period.

The GHG mitigation investments catalogued in this report likely delivered greenhouse gas emission reductions, but no connection is made between specific investments and reduction amounts. Emission reductions reported by the oil and gas industry in the North American market are shown in Table ES-1. These are reductions that occur from the various

[4] See "National Trends" at page 22.

companies' operations, such as improved efficiency in energy use in their facilities and improved fugitive emission control. Table ES-1 does not include reductions that were accomplished by other industries, like electric utilities, that were only made possible by investments by the oil and gas industry in shale gas, allowing those electric utilities to switch from coal to natural gas.

Table ES-1
Reported Emission Reductions 2011 and 2012 versus Prior Year
Oil and Gas Industry in North America
Million Metric Tons CO2e*

	Fuel Substitution	End Use	Nonhydrocarbon	Total
2011	19.8	24.3	9.0	53.1
2012	19.9	24.5	9.2	53.6

*Emissions reductions associated with fuel substitution do not include reductions by other industries such as electric utilities replacing coal with natural gas produced and sold by the oil and natural gas industry.

U.S. based oil and gas industry sources have reported direct emission reductions totaling 53.6 million metric tons CO_2 equivalent for 2012 compared to 2011. The reduction of 53.6 million metric tons is equivalent to taking 10.8 million cars and light trucks off the road,[5] or retiring nine 1000MW coal fired power plants[6]. Comparable figures for 2011 are a 53.1 million metric ton reduction and 10.6 million cars taken off the roads. For comparison, there are 246 million cars and trucks in the US, according to the U.S. Department of Transportation.[7]

Major Changes Since Last Report

Oil and natural gas companies, other private sector companies, and the Federal government continue to invest in greenhouse gas mitigating technologies in the North American market. Since the last report that covered investment from 2000-10[8], total investment in these technologies has increased by approximately $108.5 billion in the 2011-12 period, or

[5] Passenger vehicles estimate derived from http://www.epa.gov/otaq/climate/420f05004.htm, by dividing total reductions by average passenger vehicle emissions
[6] Average coal plant estimate derived from http://www.epa.gov/cpd/pdf/brochure.pdf and http://www.eia.gov/coal/production/quarterly/co2_article/co2.html by calculating total MWh/year, mmBTU/MWh and MMT CO2/mmBTU.
[7] http://www.fhwa.dot.gov/policyinformation/statistics/2011
[8] Thomas Tanton, *Key Investments in Greenhouse Gas Mitigation Technologies from 2000 Through 2010 by Energy Firms, Other Industry and the Federal Government*, October 2011

approximately 48 percent, from $227 billion to $336 billion[9]. Overall investment saw the surge that started in 2009 continue through 2011 and 2012.

[9] Note that the early reports provided estimated investments in nominal dollars; these have been adjusted to constant 2010 dollars throughout. Figures showing nominal dollars are provided in Appendix A.

Chapter I: Investments From 2000-2012

Introduction

This report summarizes identified investment in GHG mitigation technologies in North America during the period 2000 through 2012.[10] Investments are reported for the private sector and the Federal government by technology or energy category. The data were compiled from a review of over 650 company annual reports, federal budget documents, and other public sources.[11] It should be noted that most of the investments provide benefits in addition to any ability to reduce greenhouse gas emissions, and were made for multiple reasons including to increase or diversify energy supplies, or to improve efficiency.

The issue of climate change continues to draw the attention of scientists, government officials, the media and public. As climate policy in the U.S. continues to evolve, it is important to understand how current and emerging technologies including those that mitigate greenhouse gas (GHG) emissions are being employed today by major stakeholders.

Greenhouse gas emissions can be reduced by a variety of measures, such as improving energy efficiency and, in some applications, by developing alternative energy sources, like wind and solar power. Another way to reduce atmospheric emissions is to capture the CO_2 that is released from fossil fuel-fired power plants and store it underground, referred to as carbon capture and storage (CCS). This is the focus of significant attention, as power generation accounts for about one-third of CO_2 emissions from fossil fuel use. Oil and natural gas companies are reducing natural gas flaring and fugitive emissions to curb releases of methane, a potent greenhouse gas, while at the same time adding to energy supplies through various substitute fuels. The GHG mitigating technologies examined in this report were placed into four categories: *fuel substitution*, *nonhydrocarbon*, *end-use* and *enabling* technologies as laid out in the organizational chart on page iv.

This report does not include investments made by individual consumers (*e.g.* for more efficient appliances or hybrid and flexible fuel vehicles), or tax policies by the government intended to encourage specific technologies, nor monies paid in various legal settlements. Direct cash grants, such as the Federal Section 1603 grants to renewable energy generators were included.

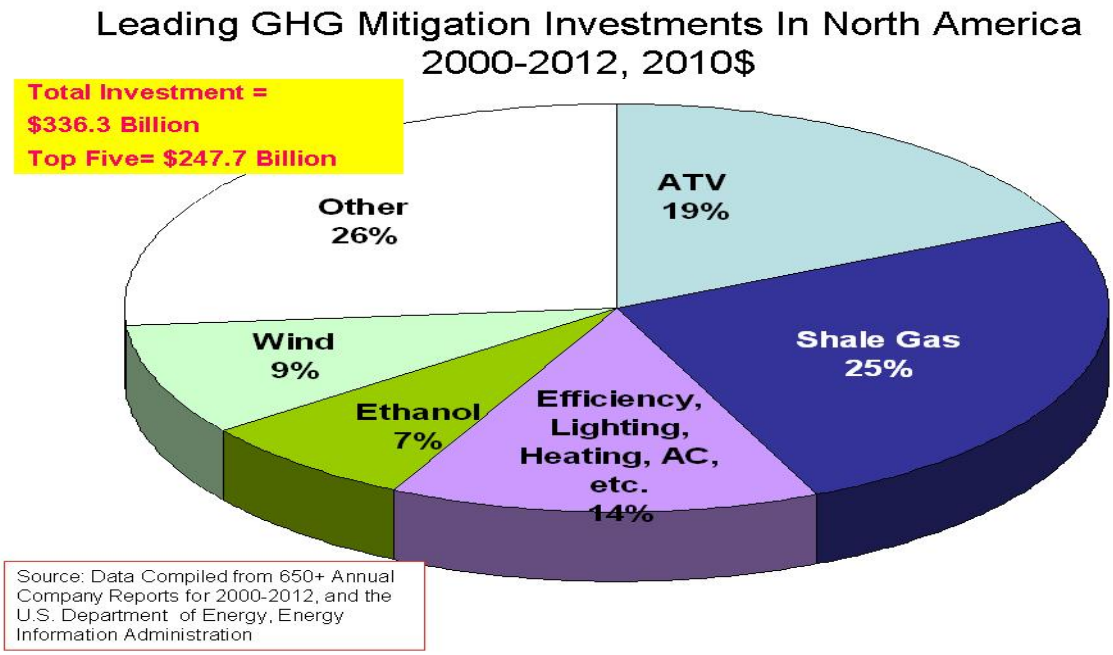
[10] No claim is made to have captured 100% of investments in each technology or for each GHG, but the author believes that further refinements to the database would change the relative distributions only at the margin.
[11] See bibliography for a list of data sources used in this study. Not all company reports reviewed provided data for the analysis undertaken in this report.

Finally, many of the project investments were made by partnerships and/or joint ventures. While all reasonable efforts were made to allocate those project expenditures to the entities involved, this was not always possible. In those instances, project level expenditures were assigned to the lead sponsor and the corresponding sector.

Six Leading Technology Investments

The five leading emission mitigation technologies for private and public sector investment (***Figure 1***), as measured by expenditure share, are: shale gas, 25 percent ($85.3 billion); advanced technology vehicles (ATV), 19 percent ($62.5 billion); efficiency, 14 percent ($47.2 billion)[12]; wind, 9 percent ($29.6 billion); and ethanol, 7 percent ($23.1 billion) primarily corn based. These top five technologies commanded 73 percent of the estimated total investments, or $247.7 billion over the 2000 – 2012 period in the North American market. All other technologies (including fugitive gas reduction, 4% and nuclear, 5%) combined comprised 26 percent of the estimated total investments.[13]

Figure 1



[12] "Efficiency" comprises all 'other' efficiency technologies except for combined heat and power (CHP) and vehicle efficiency, such as more efficient lighting, heating, ventilation, air conditioning, *etc.*

[13] Percentages may not add to 100% due to rounding.

Major Movers

During the 2000 to 2012 period, different technologies captured attention in certain years, as opportunities and challenges developed or played out. Within the oil and gas industry, the most significant technology mover was shale gas. According to the EIA, in 2011 natural gas reserves expanded to 348.8 trillion cubic feet, a 9.8% annual jump that ranks as the second largest increase on record[14]. In addition, according to EIA, exploration and production companies operating in the U.S. raised their oil reserves by nearly 3.8 billion barrels in 2011, the largest single-year increase since the government started publishing the data in 1977. The EIA now estimates that the U.S. has about 29 billion barrels of oil that are economically producible , the most volume since 1985.

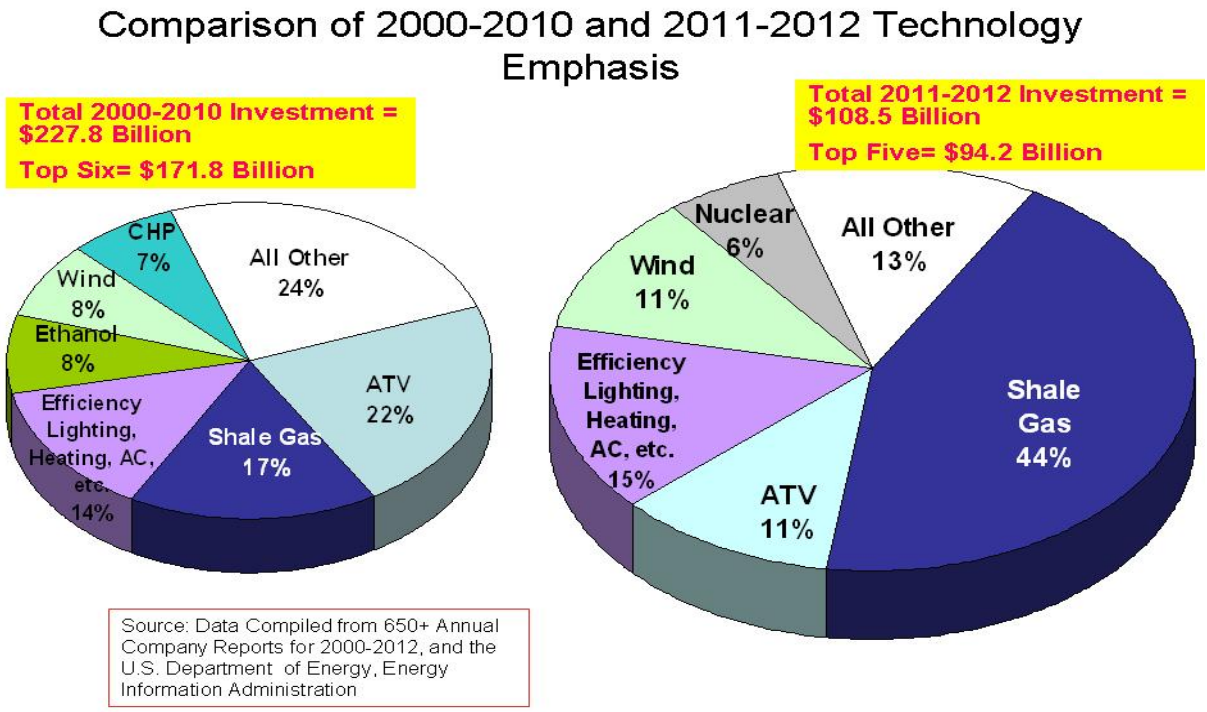
With respect to biofuels, overall investments in cellulosic ethanol for all investor types declined over the 2011-12 period as some development efforts stumbled.[15]

During 2011 and 2012 the Federal Government continued to significantly increase investments, begun in 2009 mostly under the American Recovery and Reinvestment Act of 2009 (ARRA), now reaching a total of $79.6 billion. Direct expenditures by the Federal Government helped drive a 2009 through 2012 investment surge in wind ($16 billion) and ethanol ($3.3 billion) as well as efficiency improvements ($22 billion). The Federal Government continued its increased investments in conventional technologies and fuels. Other private companies increased their investments in renewables, largely driven by the Federal government's own direct expenditures under ARRA, often in the form of direct matching grants to private sector investors. Other private sector investments were further accelerated in 2009 through 2012 by various government policies and mandates, such as state Renewable Portfolio Standards and the Federal Renewable Fuel Standard that encouraged or required investments by other private companies in wind ($2.7 billion) and ethanol production ($3.0 billion), over and above the direct Federal investments.

Figure 2 summarizes the major changes in technology focus, showing the percent of total investments in the 2000 to 2010 and 2011 to 2012 periods.

[14] http://www.eia.gov/naturalgas/crudeoilreserves/?src=home-b1
[15] http://www.financialsense.com/contributors/robert-rapier/first-commercial-cellulosic-ethanol-plant-goes-bankrupt

Figure 2



Greenhouse Gas Mitigation Technology Investments

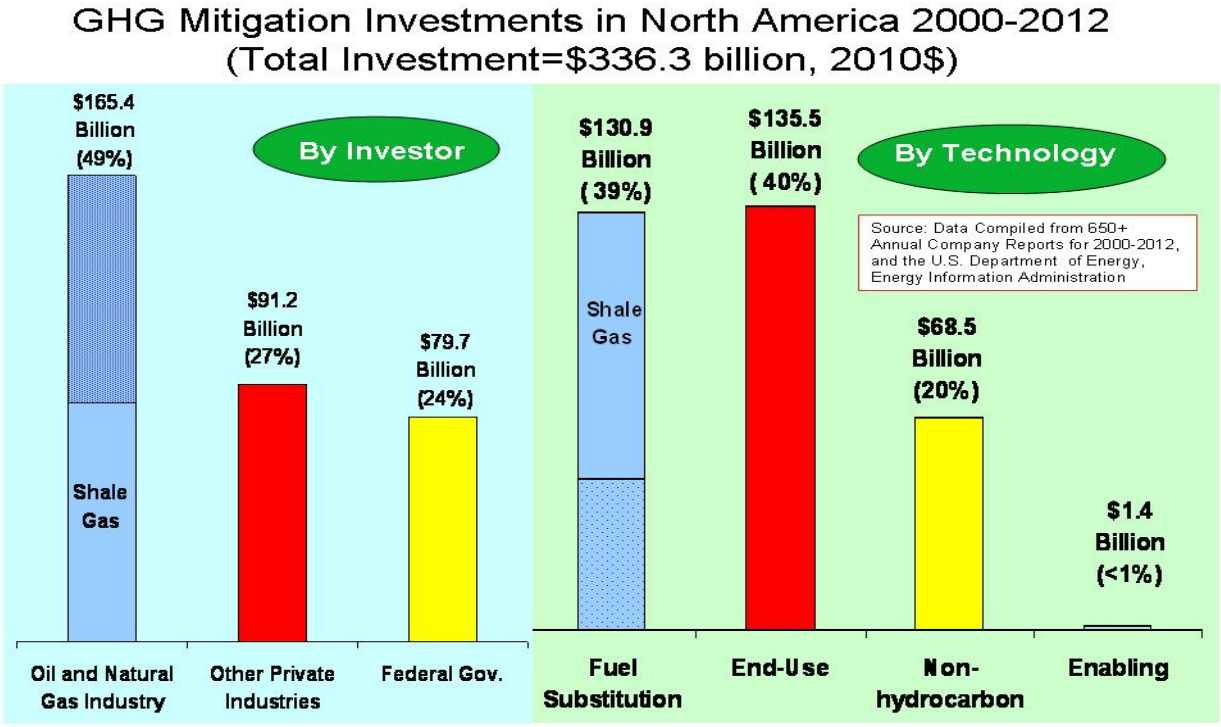
U.S. based companies[16] and the Federal government invested approximately $336.3 billion (2010 dollars) from 2000 to 2012 on greenhouse gas mitigating technologies in the North American market. The U.S. based oil and gas industry invested $165.4 billion ($81.0 billion without shale gas), 49 percent of the $336.3 billion total, in end-use, fuel substitution, non-hydrocarbon, and enabling technologies. Other private companies invested an estimated $91.2 billion or 27 percent of the total, predominantly in end-use and non-hydrocarbon technologies. During the same period, the Federal government invested in a wide array of greenhouse gas mitigation technologies, with expenditures of approximately $79.7 billion, or 24 percent of the total North American investment ***(Figure 3)***.[17]

[16] U.S. based companies include both U.S. companies and foreign-owned companies operating in the U.S.
[17] State and local alternative-energy investment would add approximately $3 billion to this total on the public-sector side. http://www.dsireusa.org/

Oil and Gas Industry Investments from 2000 through 2012

It is estimated that U.S. based oil and natural gas companies invested $165.4 billion ($81.0 billion without shale gas) from 2000 through 2012 in GHG mitigating technologies in the North American market.[18] (***Figure 4***) This expenditure represents 49 percent of the estimated total of $336.3 billion spent by U.S. companies and the Federal government. Publicly announced non-hydrocarbon investment by the U.S. based oil and gas industry in the North American market is estimated at just more than $11.4 billion over the 2000 – 2012 period, or about 7 percent of the oil and natural gas industry's investments. This represents 17 percent of the total industry and Federal government investments of approximately $68.5 billion in this technology class ***(Figure 10)***. The oil and gas industry's top publicly announced non-hydrocarbon investments continue to be in wind, biofuels, solar, geothermal, and landfill digester gas, although investments in those technologies each diminished in absolute amounts and in relation to shale gas investments.

Figure 3



The largest share of investments made by the oil and gas industry, roughly 66 percent or $109 billion, was in the fuel substitution category (Figure 4). This $109 billion investment in fuel substitution technologies represents 83 percent of the estimated $130.9 billion invested in total

[18] "North American market" is used herein to include Canada and the U.S.

in this technology class ***(Figure 11)***. Of this $109 billion, $84.4 billion, (77 percent of the oil and natural gas industry fuel substitution investment), was invested to expand shale gas development. The remaining fuel substitution technologies received $24.6 billion from the oil and natural gas industry, or 23 percent of the $109.0 billion oil and natural gas industry fuel substitution investment .

The oil and gas industry invested $44.9 billion (or 27 percent of its $165.4 billion total investments across technologies) for advanced end-use technologies, mostly for efficiency improvements including combined heat and power in the early part of the period, for carbon capture and storage[19] and for advanced technology vehicles. Significantly, this $44.9 billion investment in end-use technologies represents 33 percent of the estimated total amount ($135.5 billion) spent by all U.S. companies and the Federal government in this technology category ***(Figure 12)***.

Figure 5 shows the investment pattern over the 2000-2012 period for the oil and gas industry. Significant new levels of investment occurred between 2009 and 2012 in the fuel substitution category. This surge was driven by investments for shale gas development, as advancing technology enabled companies to efficiently develop the very large US shale gas resources. These significant new investments were made in the face of a persistent recession and slow recovery.

[19] Carbon Capture and Storage was moved from "enabling" in the May 2008 Report to "end-use" in the 2011 report and here. As described on page 24, this technology has progressed beyond basic research, with demonstration plants now under construction.

Figure 4

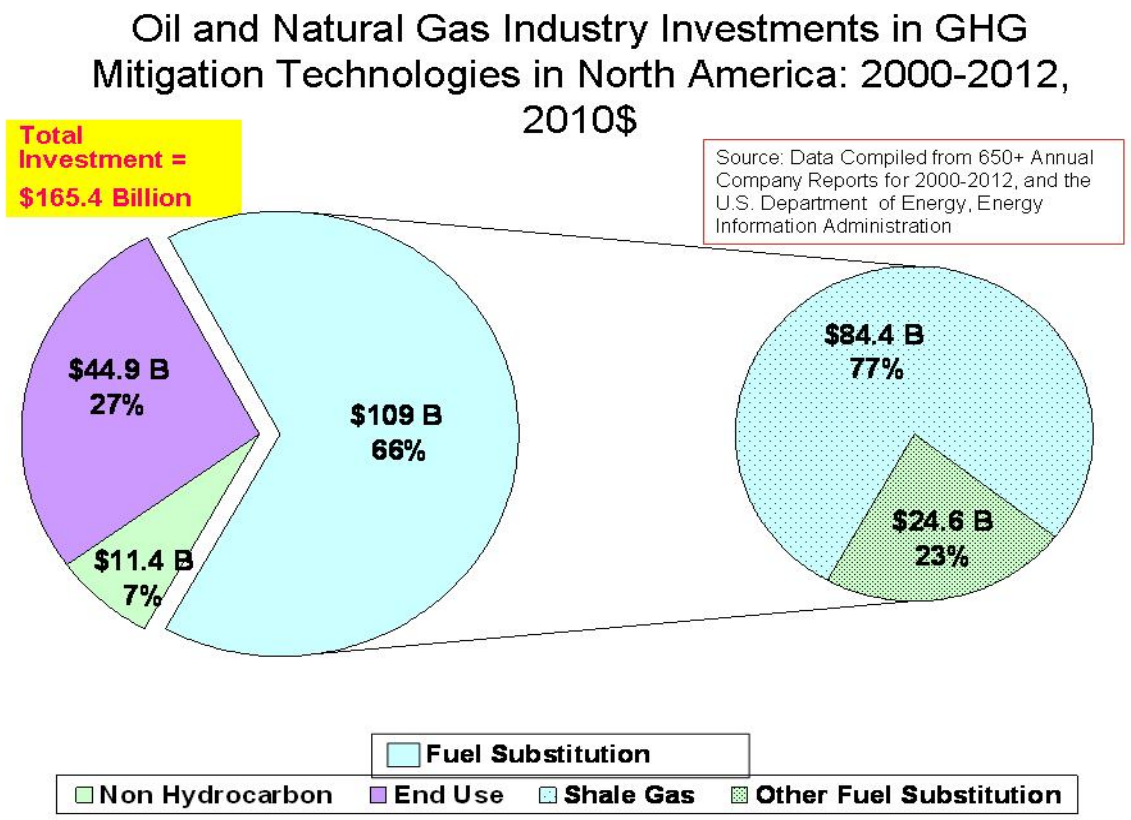
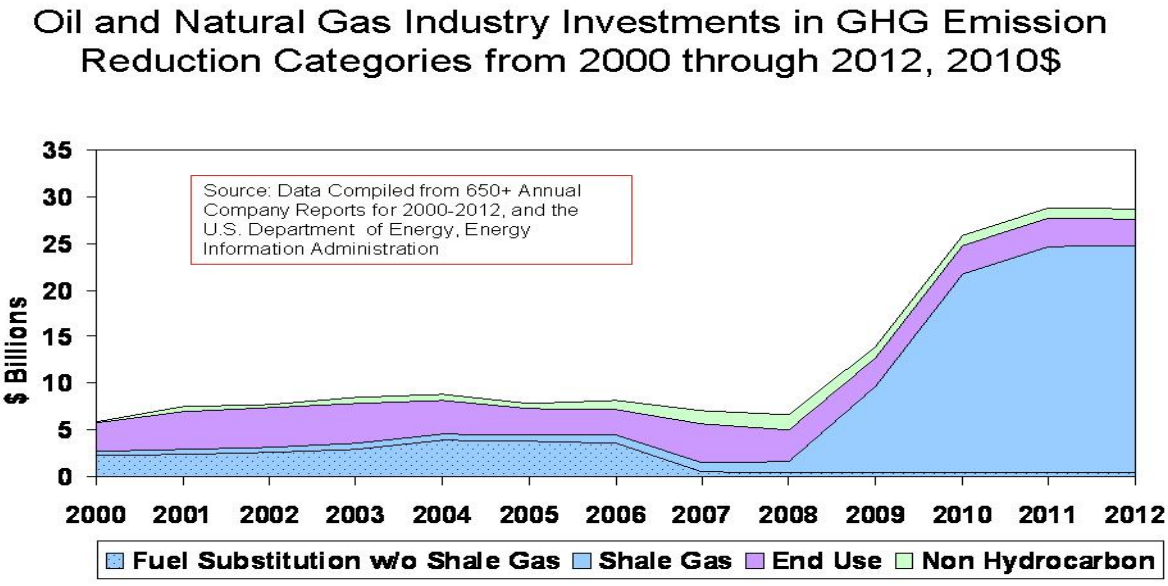


Figure 5



Other Private Industries' and Federal Government Investments from 2000 to 2012

In addition to the oil and gas industry, other significant technology investments were made by the motor-vehicle industry, agricultural industry, electric utilities, and the renewable-fuels industry. These other private industries are estimated to have invested $91.2 billion (or 27 percent of the $336.3 billion total) from 2000 to 2012 (***Figure 6***). Other private companies made significant investments in (1) the *end-use* market (mostly automotive companies investing in advanced technology vehicles), and (2) the *non-hydrocarbon* market (mostly agricultural firms and renewable fuel firms in the ethanol market, independent power producers in the electricity market, and manufacturing firms in the wind and solar markets).

Of the $91.2 billion sector total, $49.9 billion (55 percent) is associated with end-use technologies, $26.5 billion (29 percent) with non-hydrocarbons and $14.7 billion (16 percent) with fuel substitution technologies. End-use technologies include advanced technology vehicles, efficiency improvements and combined heat and power. Non-hydrocarbons include industrial gas replacements (*e.g.* for SF_6), and renewables such as wind, and ethanol. Fuel substitution technologies included a significant proportion in landfill gas recovery and in the later years significant investment in nuclear. By technology class, other private industries' investment share was 38 percent of the non-hydrocarbon investment, 11 percent of the fuel substitution category and 37 percent of the end-use category. (***Figures 10-12***).

Figure 6

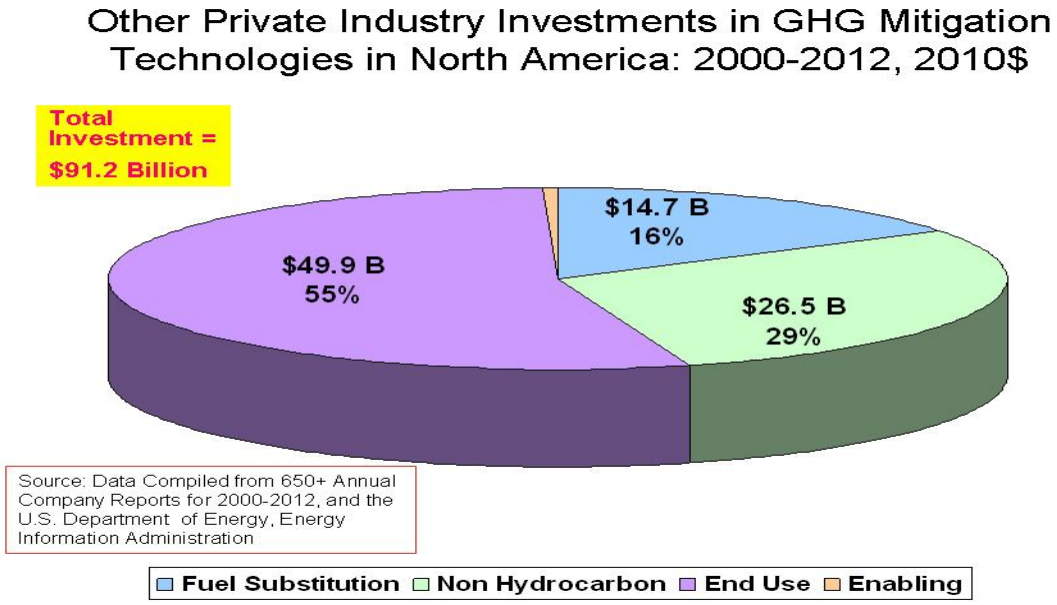
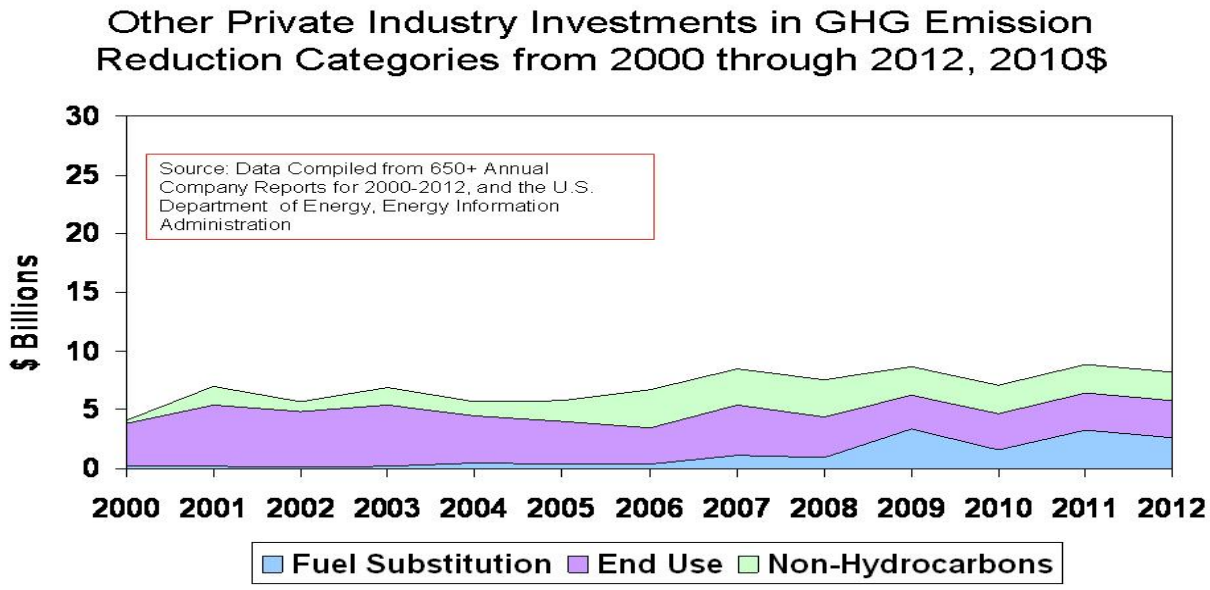


Figure 7 shows the investment pattern over the 2000-2012 period for other private companies. Significant new levels of investment occurred starting in 2009 in non-hydrocarbon technologies such as wind energy, largely driven by various states Renewable Portfolio Standards (and favorable tax credits) and the Federal Renewable Fuel Standard. Some of the investments were "matched" or otherwise encouraged by Federal expenditures under ARRA, further increasing activity by other private sector industries. In 2010, the investment level by other private industry declined compared to 2009, rebounded in 2011 and then declined again in 2012.

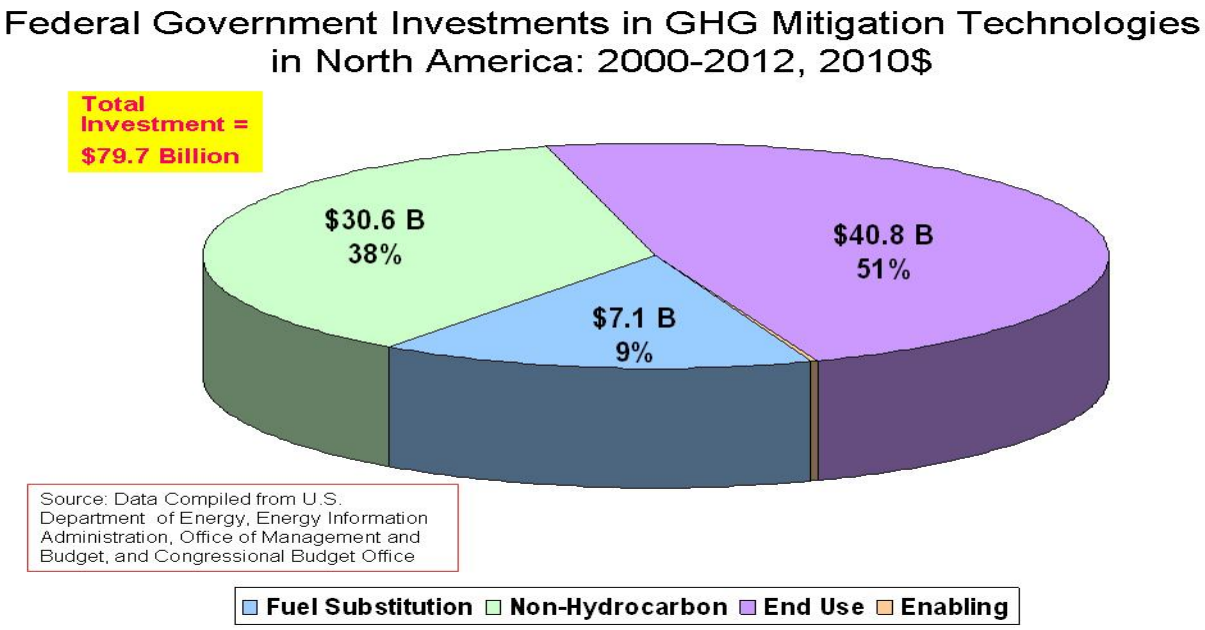
Figure 7



The Federal government (***Figure 8***) has been the most diversified investor, supporting all sixteen technologies considered in this report. Total estimated expenditure in the years 2000-2012 of $79.7 billion has been spread between fuel substitution, non-hydrocarbons (primarily ethanol, wind, and solar) and end-use (primarily advanced technology vehicles, cogeneration and lighting technologies).

Fifty-one percent, or $40.8 billion of the Federal government investment is estimated to be in end-use technology, including enhanced energy efficient lighting, combined heat and power and similar efficiency improvements as seen in Figure 8. Thirty-eight percent, or $30.6 billion of the Federal government investment is in the nonhydrocarbon class (including wind, ethanol and biodiesel), 9 percent, or $7.1 billion in the fuel substitution class (such as landfill gas and shale gas), and 2 percent fell into the enabling technology class.

Figure 8



Between 2009 and 2012 major investments were made by the Federal government in end use and non-hydrocarbons as part of ARRA expenditures, often paired with investments by private sector entities.

The estimates provided here cannot be compared directly to estimates[20] provided by the Administration and others of ARRA impacts, for the following reasons:

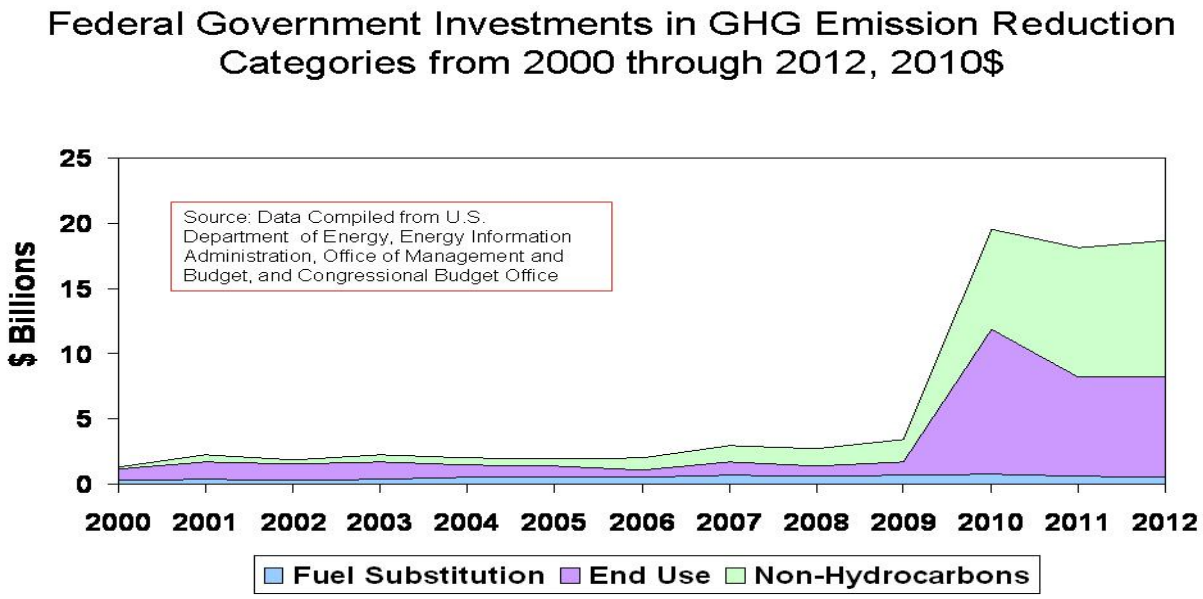
- the technologies included differ;
- this report does not include so-called green jobs training programs;
- only expenditures made were included, not those authorized or appropriated;
- and, federal tax transfers in the form of credits such as the production tax credit (PTC) and similar techniques and international assistance were not included, but direct cash grants (such as Section 1603) were.

Figure 9 shows the investment pattern over the 2000-2012 period for the Federal Government. Significant new levels of investment occurred between 2009 and 2012, especially in non-hydrocarbon measures and efficiency, mostly as a result of Department of Energy spending of

[20] See for example: http://apolloalliance.org/feature-articles/clean-energy-provisions-of-stimulus-are-consistent-with-apollo-economic-recovery-act/ , http://www.sustainablebusiness.com/index.cfm/go/news.display/id/21907 ,and http://www.whitehouse.gov/issues/energy-and-environment/

ARRA appropriations. According to the Government Accountability Office, the Federal investments under ARRA were concentrated in energy efficiency and renewable technologies.[21] Another feature of the change in the amount of Federal Government investments between 2009 and 2012, beyond the significant increase in federal spending, was the nature of federal spending. In earlier periods, federal spending was more heavily focused on early-stage development investments, particularly at the basic research stage. Now it includes later stage and commercial plants, such as the Section 1603 direct grants to wind energy facilities in lieu of tax credits.

Figure 9



Finally, it is important to recognize that aggregate investment levels for each technology are, and should be, consistent with the development status and market potential of that technology. This holds for all investor types. More mature technologies are likely to see higher levels of investment than technologies earlier in the development cycle. The technologies included here are at different stages in their development cycle and exhibit varying levels of market potential as indicated in part by relative expenditures. The distribution of investments can be expected to shift as different technologies mature or market conditions change.

[21] Frank Rusco, Director Natural Resources and Environment, United States Government Accountability Office, Testimony Before the Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives, RECOVERY ACT Status of Department of Energy's Obligations and Spending, March 17, 2011

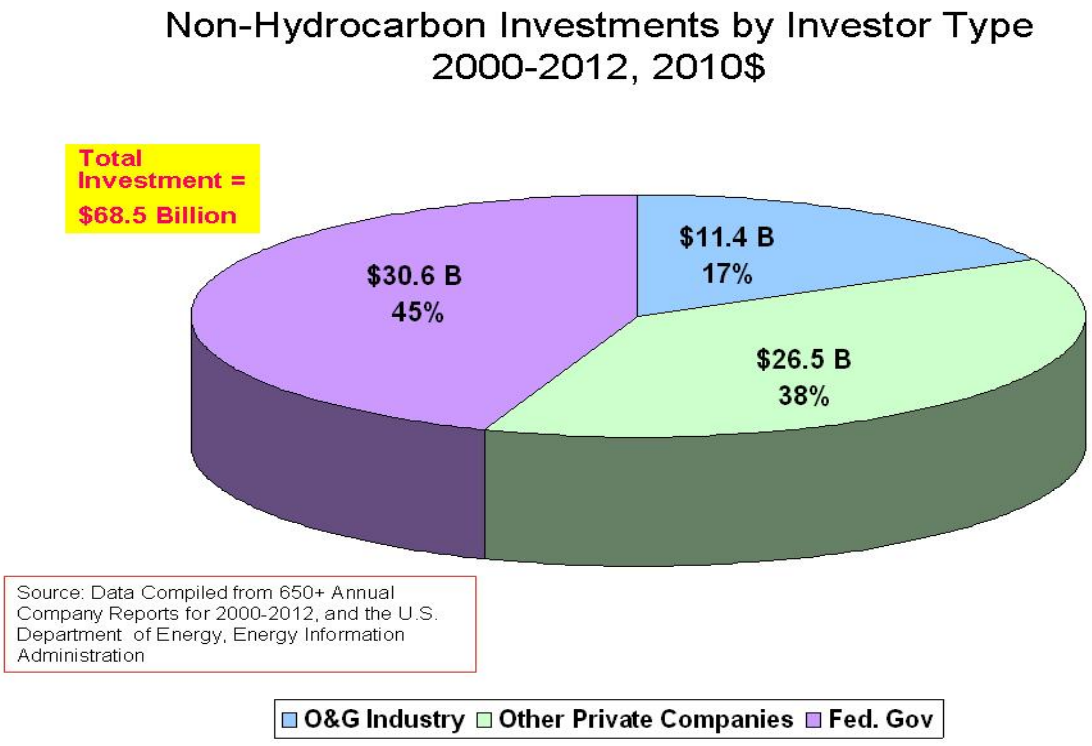
Technology Investments by Investor Types

Figures10-12 show, for each technology category, the investment shares by investor type.

Non-Hydrocarbon (10)

Other U.S.-based private companies invested roughly 38 percent of the $68.5 billion non-hydrocarbon category total from 2000 to 2012. This includes independent power producers investing in renewables like wind and solar, and agricultural and renewable fuel interests investing in ethanol production. The U.S. based oil and gas industry invested approximately 17 percent of the category total, including investments in renewables like wind and solar, as well as ethanol. The Federal government invested approximately 45 percent, spread among the renewables, ethanol and other technologies, much of it in the last four years of the 2000-2012 period.

Figure 10

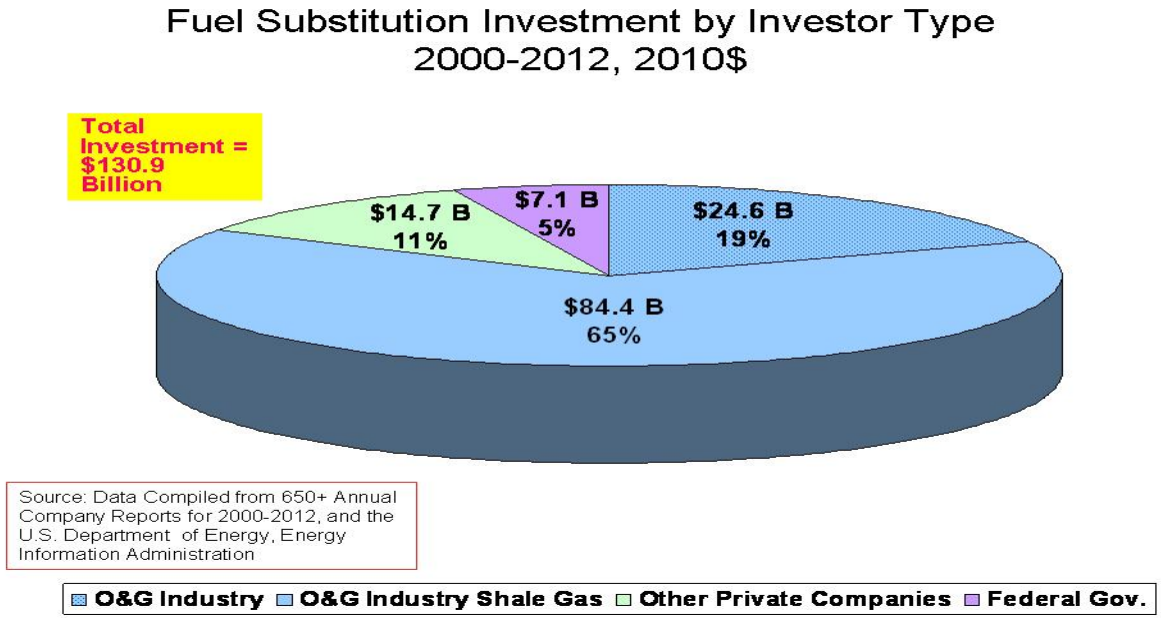


Fuel Substitution (11)

The U.S.-based oil and gas industry invested approximately 84 percent of the fuel substitution category (54% of the category total without shale gas), with significant investments in liquefied

natural gas (LNG) in early years and shifting to and increasing, dramatically, investments in shale gas in the later years. Other private companies accounted for roughly 11 percent in fuel substitution, with a significant proportion in landfill gas recovery and nuclear. The Federal government accounted for about 5 percent of this category, including investments in nuclear and landfill gas recovery as well as shale gas.

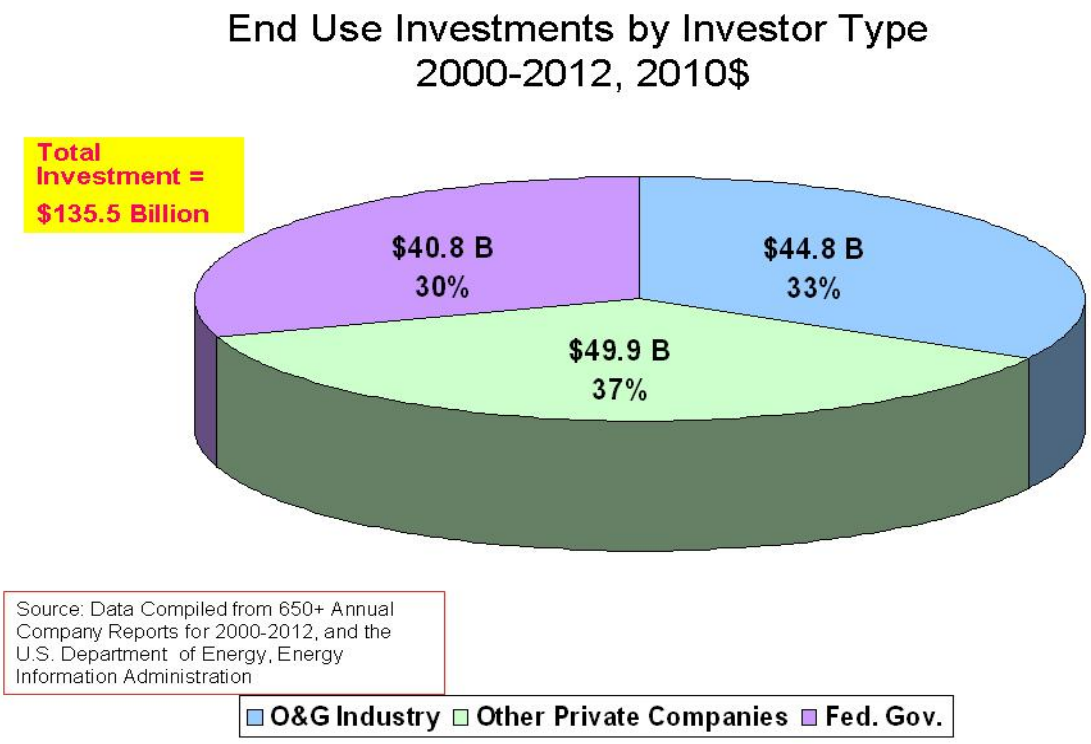
Figure 11



End Use (12)

Within the end-use category, other U.S. based industries invested an estimated 37 percent or $49.9 billion. This includes significant investments by automotive companies investing in advanced-technology vehicles, and coal companies investments, along with electric utilities, in carbon capture and storage (CCS). U.S. based oil and gas industry invested approximately 33 percent, or $44.8 billion of the $135.5 billion total investment in this technology category, principally in cogeneration, carbon capture and storage and advanced technology vehicles. Advanced batteries are an example of the advanced technology vehicle investments made by the U.S. based oil and gas industry. The Federal government invested approximately 30 percent, or $40.8 billion in the end-use category, including investments in lighting technologies and advanced technology vehicles. In the case of advanced technology vehicles, Federal Government investments are typically “matched” with investments from both oil and gas companies and, more typically, other private sector companies like automobile and battery makers.

Figure 12


End Use Investments by Investor Type
2000-2012, 2010$
Total Investment = $135.5 Billion
$40.8 B
30%
$44.8 B
33%
$49.9 B
37%
Source: Data Compiled from 650+ Annual Company Reports for 2000-2012, and the U.S. Department of Energy, Energy Information Administration
O&G Industry
Other Private Companies
Fed. Gov.

Chapter II: Emission Reductions Reported

This chapter provides a compilation of greenhouse gas (GHG) emission reduction estimates reported by the U.S. based oil and natural gas industry. The emission reduction estimates for 2008-2012 presented herein were compiled strictly from company reports including annual shareholder reports and corporate responsibility reports. The authors did not solicit, receive, or utilize any nonpublic information to develop these estimates. As discussed in the Methodology section below, there are indications that this summary of reported reductions is an underestimate of actual reductions.

Reported reductions fall into three major categories:

- *Fuel substitution*, such as increasing natural gas supply through capturing fugitive emissions, and replacing more carbon intensive fuels,
- *Non-hydrocarbon*, such as biofuels produced at biorefineries, and,
- *End-use*, including combined heat and power.

The $165.4 billion in GHG mitigation technologies made by the U.S. based oil and natural gas industry over 2000 to 2012 clearly resulted in emission reductions, both directly by the oil and gas companies and indirectly as other private companies like electric utilities switched from coal to natural gas. However, it needs to be recognized that other factors make it difficult to specifically link aggregate emission reductions and individual past investments. For example, while this report documents reported emission reductions between 2008 and 2012, investments made can often take time to complete with actual emission reductions occurring with a lag of up to five years. Some of the reductions in 2008-2012 are likely due to investments made in the early to middle years of the 2000-2012 period.

U.S. based oil and gas industry sources have reported direct emission reductions totaling 53.6 million metric tons CO_2 equivalent for 2012 compared to 2011. The reduction of 53.6 million metric tons is equivalent to taking 10.8 million cars and light trucks off the road,[22] or retiring nine 1000MW coal fired power plants[23]. Comparable figures for 2011 compared to 2010 are a 53.1

[22] Passenger vehicles estimate derived from http://www.epa.gov/otaq/climate/420f05004.htm, by dividing total reductions by average passenger vehicle emissions

[23] Average coal plant estimate derived from http://www.epa.gov/cpd/pdf/brochure.pdf and http://www.eia.gov/coal/production/quarterly/co2_article/co2.html by calculating total MWh/year, mmBTU/MWh and MMT CO2/mmBTU.

million metric ton reduction and 10.6 million cars taken off the roads. For comparison, there are 246 million cars and trucks in the US, according to the U.S. Department of Transportation.[24]

- An average of forty-one percent of the emission reductions occur in the fuel substitution category, over the period 2008-2012. This includes projects such as the installation of improved plunger lift seals and lower emission well completion technology.
- An average forty percent of the reductions are in the end use category, largely from investments in combined heat and power (also known as cogeneration) at refineries and other facilities, especially investments begun in the years prior to 2008.
- The remainder of the reductions, an average of 19 percent occur in the non-hydrocarbon category.

Table 2
Reported Emission Reductions 2008 -2012 relative to Prior Year
Oil and Gas Industry in North America
Million Metric Tons CO2e

	Fuel Substitution	End Use	Nonhydrocarbon	Total
2008 Reductions (MMT)	22.2	16.9	9.2	48.3
2009 Reductions (MMT)	22.2	21.6	9.0	52.8
2010 Reductions (MMT)	21.2	25.2	9.5	55.9
2011 Reductions (MMT)	19.8	24.3	9.0	53.1
2012 Reductions (MMT)	19.9	24.5	9.2	53.6

Emissions Reduction Methodology

This analysis reflects a compilation of reported emission reductions from company reports, including annual shareholder reports and "Corporate Responsibility Reports."[25]

While this methodology is straightforward, there are indications that it could result in an underestimation of emission reductions.

- First, not all companies reported emission reductions, so the reductions compiled here are likely conservative.
- Second, methane emission reductions reported in EPA's Natural Gas STAR program are substantially greater than the total reported here. More specifically, the 19.8 million metric tons of CO2e reductions reported for the Fuel Substitution category includes but is not limited to methane emission reductions from improved exploration and production

[24] http://www.fhwa.dot.gov/policyinformation/statistics/2011
[25] Corporate responsibility reports go by a variety of names including "sustainability reports," "citizenship" and other similar names. We use "Corporate Responsibility" here in the generic sense to include all such reports.

equipment and practices. However, EPA's Natural Gas STAR program[26] reports 2012 methane reductions from producing entities, with 65 percent reporting, of 85.9 billion cubic feet or roughly 34.8 million metric tons of CO2e. This exceeds the total reductions reported here for the entire Fuel Substitution category.

- Emissions reductions from substituting natural gas for coal are not included in reported emission reductions by oil and gas companies, but are significant in reducing overall emissions (see following section.)

Emission reductions reported were then categorized based on company descriptions of how the reductions were achieved, where such descriptions were provided. For example, reductions achieved through efficiency improvements were assigned to the end use category. Emission reductions that were reported by some companies on a global basis were prorated to the North American market using secondary sources. This was done only in the fuel substitution category, associated with emission reductions due to methane capture from fugitive emissions. In this case we used reported emission reductions from EPA's Natural Gas Star Program to prorate global emission reduction estimates to the North American market.

Some companies reported reductions (or intensity improvements) based upon their equity involvement in shared facilities (such as refinery complexes) while some reported the reductions for the entire facility, especially if they were or are the primary operator of that facility. We include reductions based on equity positions to avoid double counting. No specific link is suggested between a specific investment and emission reduction.

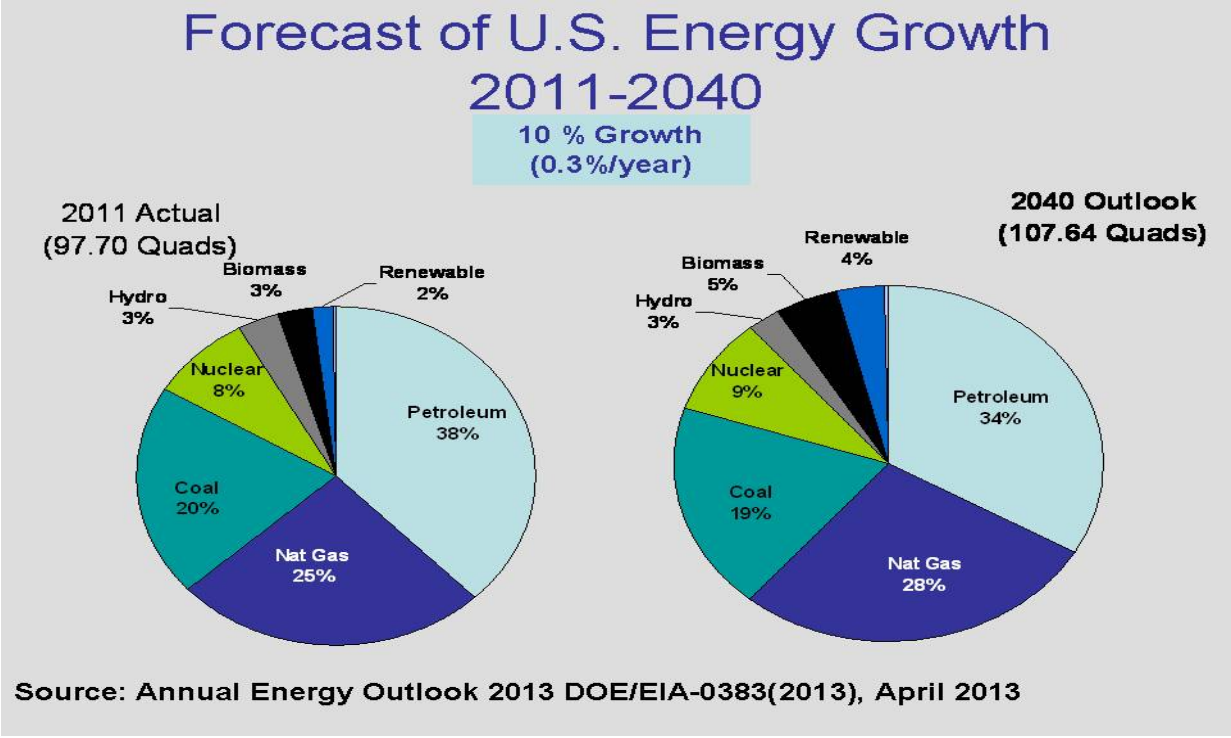
[26] See http://www.epa.gov/gasstar/accomplishments/index.html#three

Chapter III: The Challenge of Emission Reductions

Energy consumption in the United States is forecast by the Energy Information Administration (EIA), an agency of the U.S. Department of Energy, to increase approximately 10 percent over the 2011 to 2040 period, or about 0.3 percent annually. (***Figure 13***) This increase is projected after accounting for a predicted improvement in energy intensity (energy usage per real dollar of GDP).[27]

To meet increased demand for energy, the EIA projects that hydrocarbons (crude oil and natural gas and their derivatives) will remain the mainstay of the U.S. energy sector at least over the next several decades. The market share of oil, natural gas, and coal is projected to be approximately 81 percent in 2040, little changed from 83 percent in 2011.

Figure 13

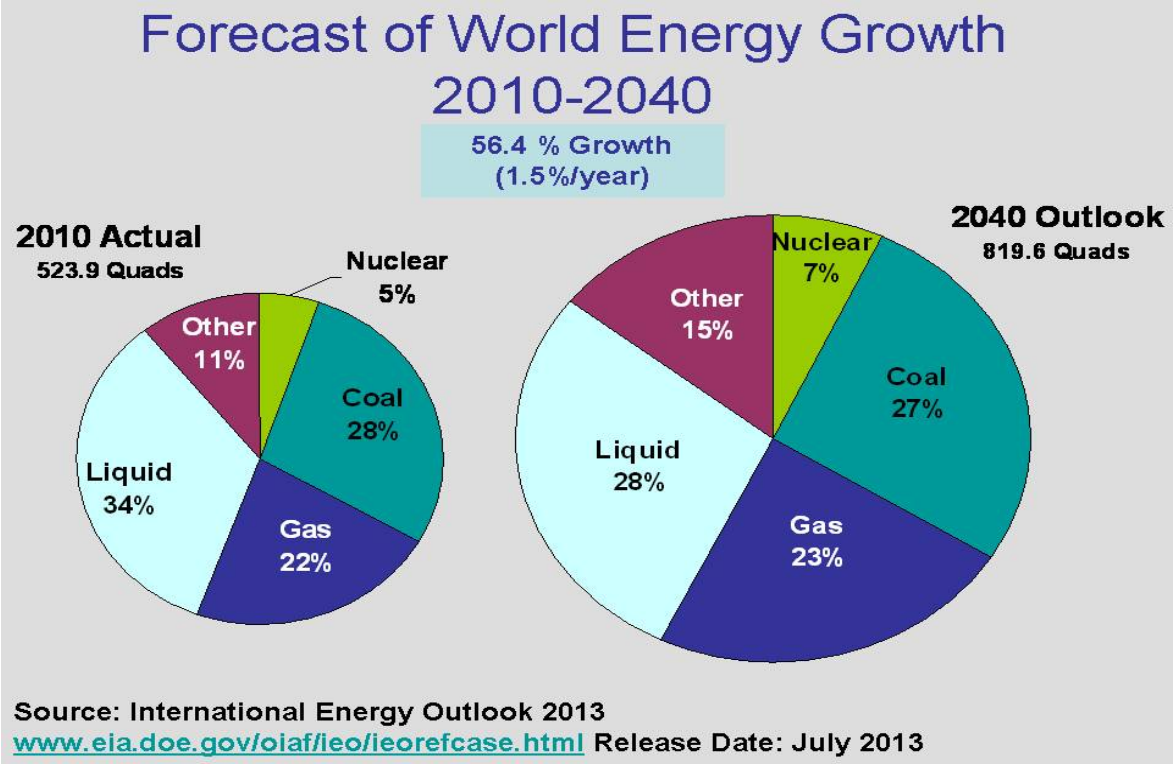


According to EIA, global energy consumption is projected to rise by approximately 56 percent over the 2010 to 2040 period, a roughly 1.9 percent annual increase, led by developing countries, many of which are expected to significantly increase energy consumption due to rising per capita incomes and population growth. (***Figure 14***) Similar to the forecast for the

[27] Noted trends and statistics in this section are from Energy Information Administration, *Annual Energy Outlook 2013*, April 2013

U.S., fossil fuels are estimated to fill roughly 78 percent of the projected global primary energy demand in 2040.

Figure 14



Natural gas is the fastest-growing fossil fuel in the outlook. Global natural gas consumption increases by 1.7 percent per year. Increasing supplies of tight gas, shale gas, and coalbed methane support growth in projected worldwide natural gas use. Coal use grows faster than petroleum and other liquid fuel use until after 2030, mostly because of increases in China's consumption of coal and tepid growth in liquids demand attributed to slow growth in the OECD regions and high oil prices.

These projections of energy demand highlight the importance of continued economically viable investments leading to more efficient, and lower-GHG emitting technologies, as well as the development of efficient technology transfer programs to developing countries.

National Trends

There has been significant progress in mitigation of U.S. GHG emissions although significant challenges remain going forward.[28]

After two years of declining carbon dioxide emissions (2008 and 2009) and one year of increasing emissions (2010), carbon dioxide emissions in 2011 fell, but at a less dramatic rate than in 2009. Unlike 2009, the 2011 decline occurred during a year of positive growth in the Gross Domestic Product (GDP).

In 2010 GDP grew by 3.0 percent, and emissions increased by 3.9 percent. While changes in emissions are highly correlated with economic activity, there are additional factors that influence changes in emission levels. Since 1990, carbon dioxide emissions in the United States have grown much more slowly than GDP; in 2007 emissions reached a peak of 20 percent more than 1990, following the 2010 increase, carbon dioxide emissions fell to about 12 percent more in 2012 compared to 1990. GDP has increased by 63 percent over that same time period.

While the U.S. economy declined by 2.6 percent in 2009, a 5.8-percent decrease in total greenhouse gas emissions meant that U.S. greenhouse gas intensity improved by 3.2 percent from 2008 to 2009. From 2009 to 2010, that was reversed slightly, with a 0.7% increase in intensity. Since about 2000 the energy intensity of the economy has improved by an average of 1.7 percent per year, as natural gas has increasingly substituted for coal, and other fuel substitutions and efficiency improvements continued to grow, although not in every single year.

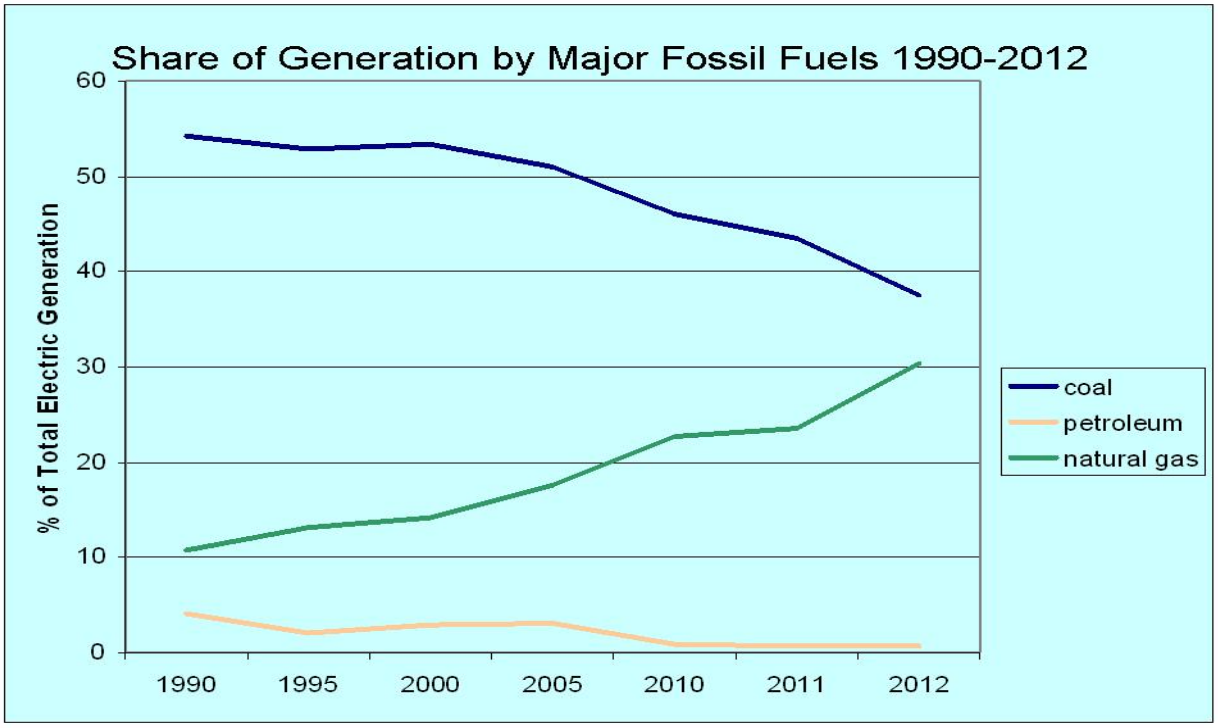
In 2011, GDP grew by 1.8 percent, but emissions decreased by 2.4 percent (136 million metric tons). This indicates that the carbon intensity of the economy improved by about 4.2 percent. The 2011 decrease is only the fourth year since 1990 to experience a decline in carbon intensity of greater than 3.5 percent for the economy as a whole and only the sixth year since 1990 to experience an emissions decline.

As recently as 2005, coal's share of electric power sector generation was over 51 percent. By 2012 that share had declined to just over 40 percent. Petroleum generation, which was small to begin with, has also lost share. Natural gas, on the other hand, had grown in market share. The introduction of new, efficient gas-fired capacity and a recent decline in the price of natural gas has helped boost natural gas' share from 14 percent in 2000 to 30 percent in 2012. Figure 15

[28] Noted trends and statistics in this section are from Energy Information Administration, *U.S. Energy-Related Carbon Dioxide Emissions, 2011* Release Date: August , 2012

shows year-by-year changes in electric power generation fuel, enabled by dramatically lower natural gas prices brought about by shale gas development. According to EIA, since May 2012, a combination of an up-tick in prices for natural gas and increased demand for electricity during the summer months led electric systems across much of the country to increase their use of coal-fired units. In March 2013, coal-fired units generated a little over 130,000 MWh of electricity, while natural gas units produced nearly 85,000 MWh[29].

Figure 15

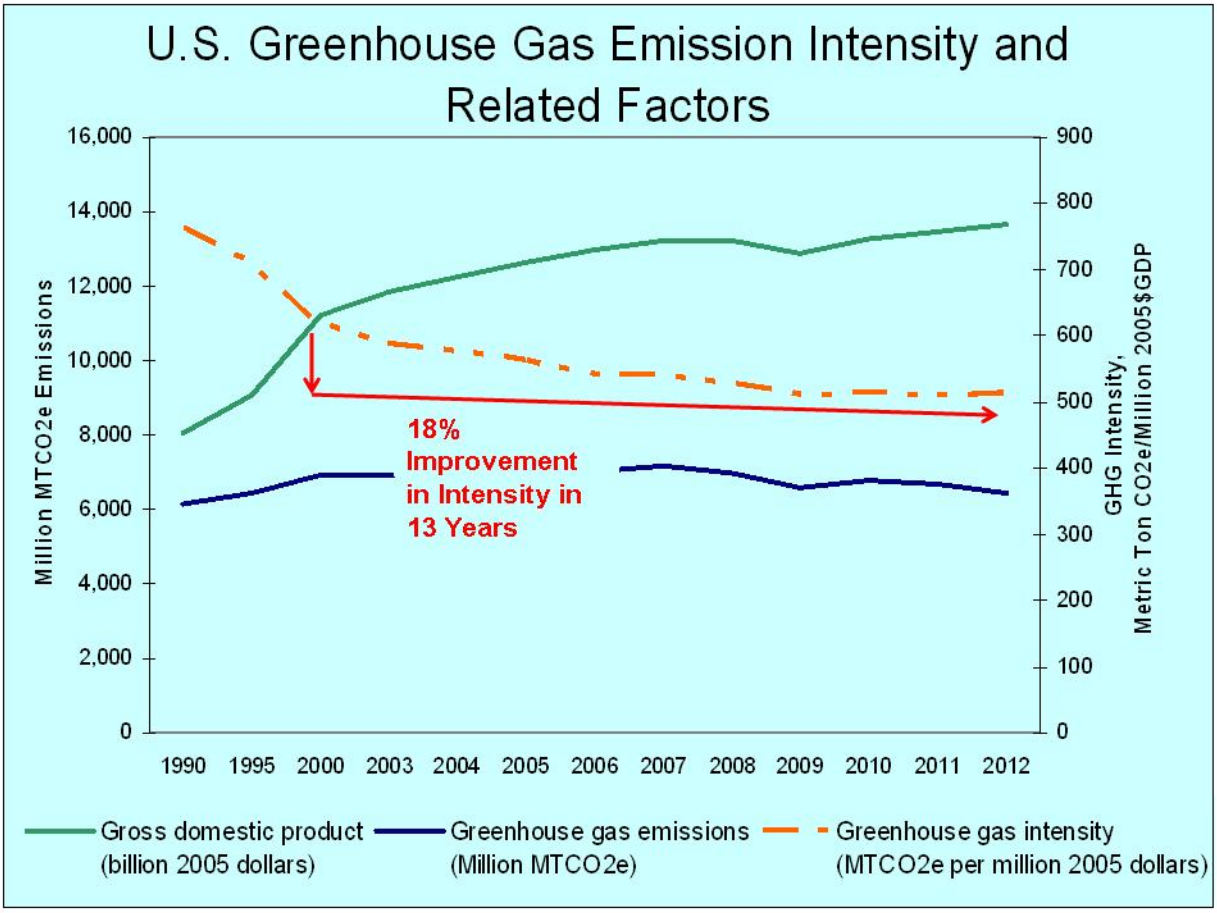


Source: http://www.eia.gov/environment/emissions/carbon/ and
http://www.eia.gov/todayinenergy/detail.cfm?id=11391#

From 2000 through 2012, the overall carbon dioxide intensity of the U.S. economy—measured as metric tons carbon dioxide equivalent ($MTCO_2e$) emitted per million dollars of gross domestic product (GDP) — improved by more than 18 percent or 1.4 percent per year, as shown in Figure 16. Oil and gas industry investments over the last decade in GHG mitigating technologies have contributed to this improving trend.

[29] http://www.eia.gov/todayinenergy/detail.cfm?id=11391

Figure 16



Source: Energy Information Administration, *U.S. Energy-Related Carbon Dioxide Emissions, 2011*, Release Date: August, 2012 and http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2013&subject=0-AEO2013&table=17-AEO2013&region=1-0&cases=ref2013-d102312a

The U.S. Energy Information Administration[30] estimates that, with improved efficiency of energy use and a shift away from the most carbon-intensive fuels, U.S. energy-related carbon dioxide (CO2) emissions will remain more than 5 percent below the 2005 level, even through 2040. Estimates made by EIA in 2013 of emissions from motor gasoline demand are lower than EIA projections made in 2012. EIA attributes the lower emissions to be the result of the adoption of more efficient automotive technology, and shifts in consumer behavior. Emissions from coal use in the generation of electricity are expected to continue downward as power generation shifts away from coal to lower-carbon fuels.

CO2 emissions per 2005 dollar of GDP (carbon intensity) have historically tracked closely with energy use per dollar of GDP. The U.S. EIA estimates, however, that as lower-carbon fuels account for a larger share of total energy use, CO2 emissions per 2005 dollar of GDP will

[30] U.S. EIA, *Annual Energy Outlook, 2013*, April 2013

decline more rapidly than energy use per 2005 dollar of GDP, falling by 56 percent from 2005 to 2040, at an annual rate of 2.3 percent per year further improving our carbon intensity.

The most recent analysis by EIA of global emissions[31] has non-OECD Asia accounting for 70 percent of the world's increased CO2 emissions through 2040. China's share of global energy-related CO2 emissions is projected to grow from 21 percent in 2007 to 32 percent in 2040. India accounts for the second-largest share of the projected increase, 7 percent. The U.S. share of world CO2 emissions is projected to fall to 12.5 percent (5691 MMT out of a global total of 45,455 MMT) in 2040, from about 19.5% today, although the improvement is likely to be even more pronounced with the larger improvements in carbon intensity, as described above, through 2040.

Greenhouse Gas Emission Mitigation Technologies

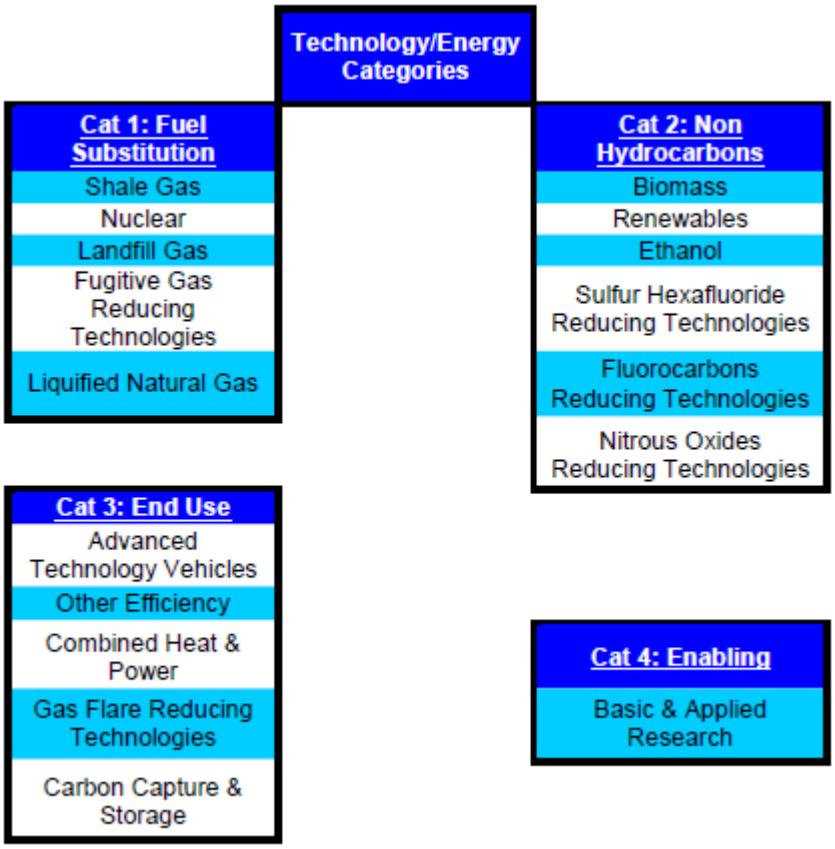
A principal objective of this report is to identify key technologies and their associated investments that mitigate GHG emissions, or that have the potential to do so in the future. Sixteen major energy technologies have been identified in this study as actual or potential mitigation technologies. These technologies have been grouped into four categories (***Figure 17***): *fuel substitution*, (five technologies), *nonhydrocarbon* (six technologies), *end-use*[32] *(*five technologies*)*, and *enabling*. Biomass, within the non-hydrocarbon category, is further delineated into electricity and transportation applications, and ethanol is separated into corn and cellulosic ethanol. Sugar cane is not included here as it is not a major source in the North American market.

[31] U.S. EIA *International Energy Outlook 2013*, July 2013

[32] Carbon Capture and Storage has been moved from "enabling" in the May 2008 Report to "end-use" in the 2011 and later reports..

Figure 17

Categorization of GHG Mitigating Technologies[33]



Category 1. "*Fuel substitution*" technologies include shale gas, liquefied natural gas (LNG), nuclear, landfill gas, and methane captured by fugitive gas reducing technologies.

- *Shale Gas* is an important source of expanded supply of natural gas in the U.S. As a greenhouse gas emission reduction technology, shale gas increases the supply of natural gas to the North American market that may substitute for coal, and to a lesser extent for petroleum-based liquid fuels. The potential for greenhouse gas mitigation is determined, however, by the amount of gas-on-gas substitution versus gas-on-coal. Several recent studies demonstrate the greenhouse gas emission reductions are associated with substituting shale gas for coal and other higher GHG intensity fuels. The Massachusetts Institute of Technology (MIT) Energy Initiative found:
    - "the role of natural gas is likely to continue to expand, and its relative importance is likely to increase even further when greenhouse gas emissions are constrained."[34]

  MIT further found that replacement of coal by natural gas in U.S. electric generation would involve the "substitution of coal units with an average efficiency of 30% to 35% with gas combined cycle plants with efficiencies in the range of 45% to 55%."[35]

[33] In previous editions of this Report, "Fugitive Gas Reducing Technologies" was placed in the End Use Category in this chart.
[34] MIT Energy Initiative – Future of Natural Gas, Abstract, p. ix, June 2011

Similarly the International Energy Agency in their World Energy Outlook 2011 – Special Report – "Are We Entering a Golden Age of Gas?" concluded that "shale gas produced to proper standards of environmental responsibility has slightly higher 'well-to-burner' emissions than conventional gas, with the combustion of gas being the dominant source of emissions."[36] (emphasis added) The National Energy Technology Laboratory (NETL) provided relative lifecycle GHG emission factors[37]:

- Average Coal: 2,453 lbs CO2e per MWh;
- Average Conventional [natural] Gas; 1,041 CO2e per MWh;
- Average Unconventional [natural] Gas: 1,139 CO2e per MWh.

- *Liquefied natural gas* (LNG) is natural gas that has been super-cooled to a liquid. This dramatically reduces the volume for cost-effective transport in ships (where transport via conventional natural gas pipelines is cost prohibitive or not feasible). LNG as a transport mode opens up natural gas to become a much more broadly traded international commodity.

- *Nuclear* is limited to the production of electricity and reduces the amount of coal or natural gas consumption for that purpose, and consequently the associated greenhouse gas emissions.

- *LFG* is landfill gas (methane) produced by the anaerobic digestion of waste material. Historically, that methane was emitted into the atmosphere, but more recently has been collected and used to produce electricity or in transportation applications. According to the Environmental Protection Agency, of the 2,300 or so currently operating or recently closed municipal solid waste landfills in the United States, more than 510 have LFG utilization projects.[38] The generation of electricity from LFG makes up about two–thirds of the currently operational projects in the United States, with the remainder in direct use (heat) and transportation application. LFG acts to reduce greenhouse gas emissions first by reducing the amount of methane released to the atmosphere, and secondarily by substituting for higher-carbon content fossil fuels such as coal and petroleum.

- *Fugitive Gas* Emissions can occur when methane, a potent greenhouse gas, is collected and transported, and certain amounts leak out to the atmosphere. Investments made to reduce fugitive emissions directly and indirectly reduce greenhouse gas emissions. Emissions may indirectly be reduced as lower carbon natural gas is added to the fuel supply.

Category 2. "Non-hydrocarbon" technologies include any energy form that is not a hydrocarbon energy source. This category includes: wind energy conversion, solar to electric, geothermal (electric and direct use for industrial application), biomass and biorefinery, biodiesel, and ethanol production. Ethanol and biodiesel production were included in this category rather than

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[35] MIT Energy Initiative – Future of Natural Gas, Appendix 1A; Life-Cycle Climate Impacts from Fossil Fuel Use, p. 2, June 2011

[36] International Energy Agency – World Energy Outlook 2011 – Special Report – "Are We Entering a Golden Age of Gas?" p.7, 2011

[37] National Energy Technology Laboratory – *Life Cycle Greenhouse Gas Analysis of Natural Gas Extraction & Delivery in the United States*, Timothy J. Skone, May 12, 2011

[38] http://www.epa.gov/lmop/faq/lfg.html

in the fuel substitution category where they could have also arguably been placed. This category also includes technologies that facilitate reductions in halogenated fluorocarbons (HFC), perfluorocarbons and sulfur hexafluoride (SF_6).

- *Ethanol* is currently produced by the fermentation of various sugars and starches, primarily from corn and sugar cane. Significant fossil fuel use is involved in corn-based ethanol production both for growing the corn and in producing the ethanol. Most ethanol for fuel is produced in Brazil or the United States. Technological advances may allow ethanol production from cellulosic materials in the longer term. Greenhouse gas emissions benefits associated with corn-based ethanol are likely to be marginal or zero[39], and there is significant uncertainty surrounding greenhouse gas emissions benefits associated with cellulosic ethanol, although they are expected to be better than corn based ethanol.

  As part of revising the National Renewable Fuel Standard program (commonly known as the RFS program) as required by the Energy Independence and Security Act of 2007 (EISA), EPA has analyzed lifecycle greenhouse gas (GHG) emissions from increased renewable fuels use. In February 2010 EPA determined that ethanol produced from corn starch at a new natural gas, biomass, or biogas fired facility (or expanded capacity from such a facility) using advanced efficient technologies will achieve about 20% GHG emission reduction compared to the 2005 gasoline baseline.[40]

- *Biomass* projects also use plant or animal waste materials to produce energy either from direct combustion, through thermal gasification, or biologic treatment. Biomass gasification is included in biomass/biorefining, as a precursor to ultimate use, within the nonhydrocarbon group.

- *Bio-refineries* produce a broad slate of products from plant materials, including energy and fuels, plastics, pharmaceuticals and animal feeds. Biodiesel is produced by chemically altering oils (e.g., soybean oil) into diesel fuel substitutes. Also included are other bio-derivatives including those produced as refinery products, such as certain alcohols and alkanes. Another sub-category of biologically derived petroleum substitutes are called biobased products (or bioproducts).

- *Solar, wind and geothermal* are electricity generation technologies that substitute for fossil-based generation technologies. Because, wind and solar can be intermittent in their output, they often require other power plants on a grid to operate in less efficient modes of operation—termed ramping—which can result in reduced or no reductions in fuel use and GHG emissions.

- *Sulfur hexafluoride (SF_6) and Halogenated Fluorocarbons/Perflurocarbons* are gases used in industrial applications and refrigeration. Various substitute gases have recently been developed to reduce those applications' greenhouse gas emissions, or their global warming potential. These gases substitute for other industrial and commercial gases, but are not "fuels" and not considered as fuel substitutes.

[39] National Research Council. *Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy*. Washington, DC: The National Academies Press, 2011.
[40] http://www.epa.gov/otaq/renewablefuels/420f10006.htm

- *Nitrous Oxides* (N_2O) are produced by both natural and human sources. Primary human-related sources of N_2O are agricultural soil management, animal manure management, sewage treatment, adipic acid production, and nitric acid production. Nitrous oxide is also produced naturally from a wide variety of biological sources in soil and water, particularly microbial action in wet tropical forests. Control mechanisms for human sources include improved tillage practices and fertilization techniques, and improved efficiency in manufacture of adipic acid and combustion.

Category 3. "*End-use*" technologies include stationary fuel-cell applications[41], transportation applications (fuel cell, electric hybrid, and flex-fuel vehicles, high efficiency gasoline and diesel engines), and cogeneration—regardless of fuel source. The extent of greenhouse gas mitigation from flexible fuel vehicles depends on the consumers' actual use of different fuels, and may be negligible. This category also includes investments made to improve thermodynamic efficiency.

- *Advanced-Technology Vehicles* use both petroleum and non-petroleum based fuels (or mixtures), advanced batteries for hybrid vehicles or fuel-cell technologies. Automakers, engine manufacturers, and oil and gas companies are actively developing vehicle technologies and the advanced fuels of the future that will power them.

- *Cogeneration*, or *combined heat and power* (CHP) is the simultaneous production of both electricity and thermal energy (steam, hot water, hot air). CHP is an important efficiency improvement compared to separate production of electricity and heat. These facilities range from very small units in commercial buildings to large units at petroleum refineries, and are captured separately from other efficiency improvements.

- *Efficiency* measures include a whole range of technologies, from improved combustion burners, to advanced lighting, and improved process efficiencies, but does not include, for purposes of this report, combined heat and power.

- *Gas Flaring* can occur when methane associated with crude oil production is combusted. In areas of the world lacking infrastructure and markets, this associated gas is usually flared (burned) or sometimes vented (emitted as un-burnt gas). Reducing this flared gas reduces greenhouse gas emissions of either CO_2 if the gas is burned, or of methane if the gas is vented. Safety issues may impact the flaring or venting decision.

- *Carbon Capture and Storage* is the capture and long-term storage of carbon dioxide emissions from combustion processes. Over 200 CCS projects were active or planned worldwide at the end of 2010, a net rise of 26 from 2009[42]. Of these, 77 are large-scale integrated projects at various stages of development. North America, Europe, and Australia are home to 87% of all projects. This technology has moved beyond the basic research stage.

Category 4. "Enabling Technologies" are necessary and often basic science and technology that allow other technologies' use. They include various consortia that are researching and developing a wide variety of technologies, and include several university programs. Their basic and cross cutting application does not allow categorization into one of the other categories.

[41] Note that fuel cells as a technology are not separately listed, as they depend on a variety of fuels and can be used in a variety of applications, including transportation and combined heat and power. They are subsumed in the various categories where applicable.
[42] *Carbon Capture and Storage: A Mixed Review,* Robin Beckwith, JPT/JPT Online, May 2011

Investment Estimates Methodology

This analysis was carried out in several steps. The first was an identification of major categories of emerging energy sources, and the associated emissions control/reduction technologies. Second, a database of investments was constructed by GHG mitigation technology category and by investor type. The database was compiled from a review of over 650 publicly available company annual reports, federal budget documents, and other public sources, beginning with the database constructed for the 2011 report, *Key Investments in Greenhouse Gas Mitigation Technologies by Energy Firms, Other Industry and the Federal Government:* October 2011. No confidential or non-public company investment information was sought, received, or utilized. If an investment amount for a relevant technology was specified in a source document it was included in the database. All investments were initially tabulated in nominal dollars. Because the investments covered in this report have occurred over a thirteen-year period, it is appropriate to adjust the annual data for the inflation that has occurred over the study period. Given that most investments in greenhouse gas mitigation technology covered in this report are spread across many sectors of the economy, the deflator chosen to convert the annual data to 2010 dollars was the U.S. Department of Commerce, Bureau of Economic Analysis chain-type deflator for "Gross Private Domestic Investment."[43]

Third, each investment was reviewed to determine if it should remain in the database, be prorated, or otherwise adjusted from a global level to the North American market. For example, we identified three major types of investments for LNG: liquefaction, regasification facilities, and ships. We have only included investments in North American LNG regasification facilities. The global LNG market also includes investments in ships, and liquefaction facilities in foreign and domestic locations. Investments in ships and liquefaction facilities were not included in the data base as they, to a large extent, fall outside the area of the North American market.

[43] Available at http://research.stlouisfed.org/fred2/series/GPDICTPI?cid=21

Appendix A
Figures Presented in Nominal Dollars

Figure A-1

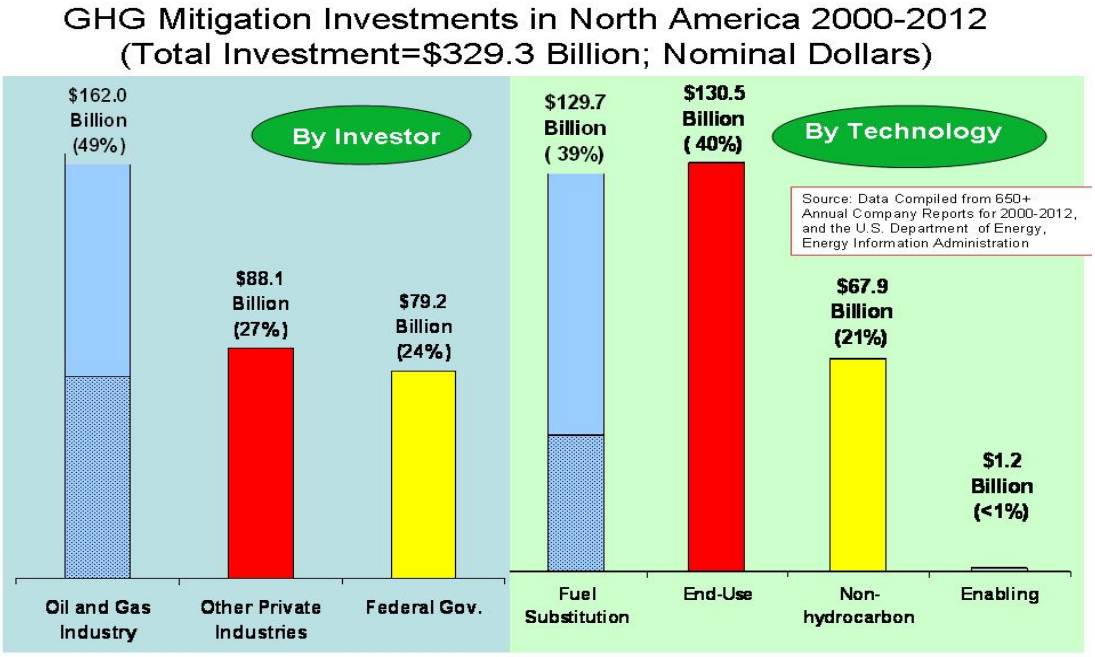


Figure A-2

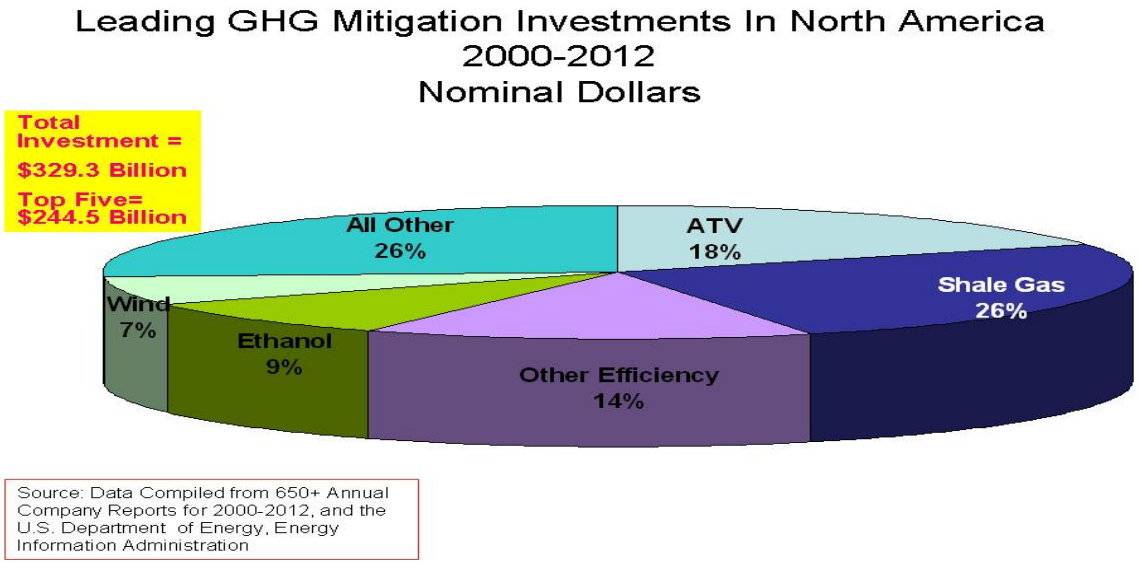


Figure A-3

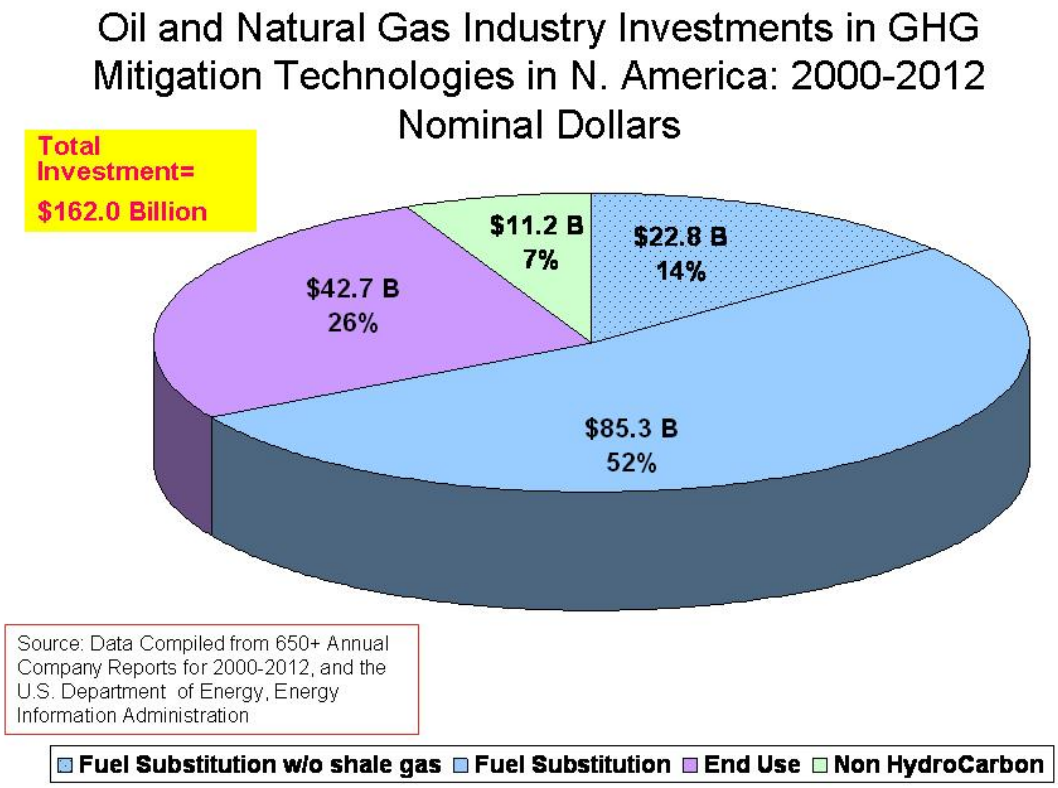


Figure A-4

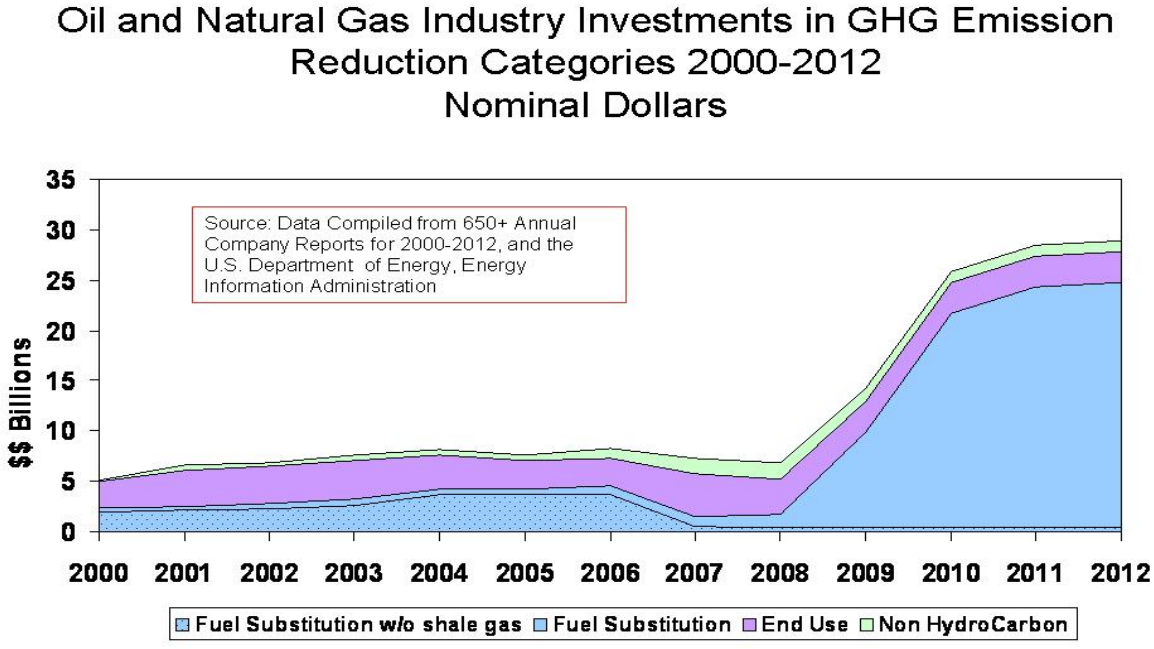


Figure A-5

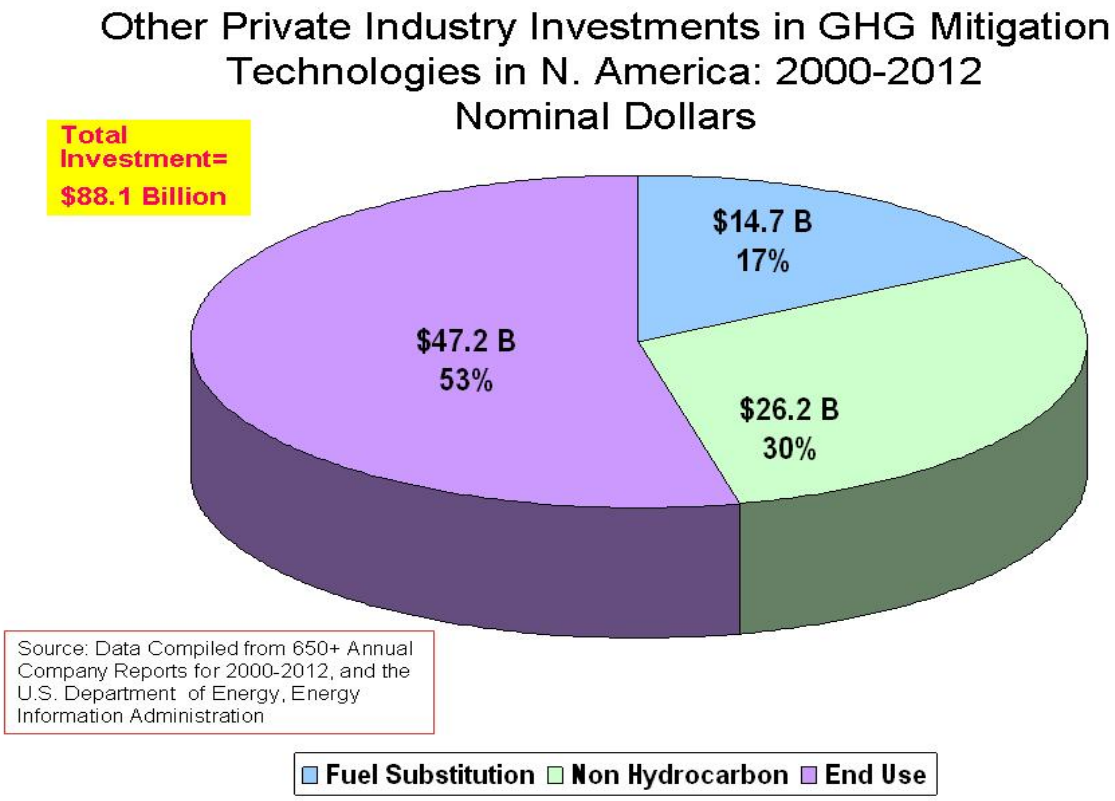

Other Private Industry Investments in GHG Mitigation Technologies in N. America: 2000-2012
Nominal Dollars
Total Investment= $88.1 Billion
$14.7 B 17%
$26.2 B 30%
$47.2 B 53%
Source: Data Compiled from 650+ Annual Company Reports for 2000-2012, and the U.S. Department of Energy, Energy Information Administration
Fuel Substitution
Non Hydrocarbon
End Use

Figure A-6

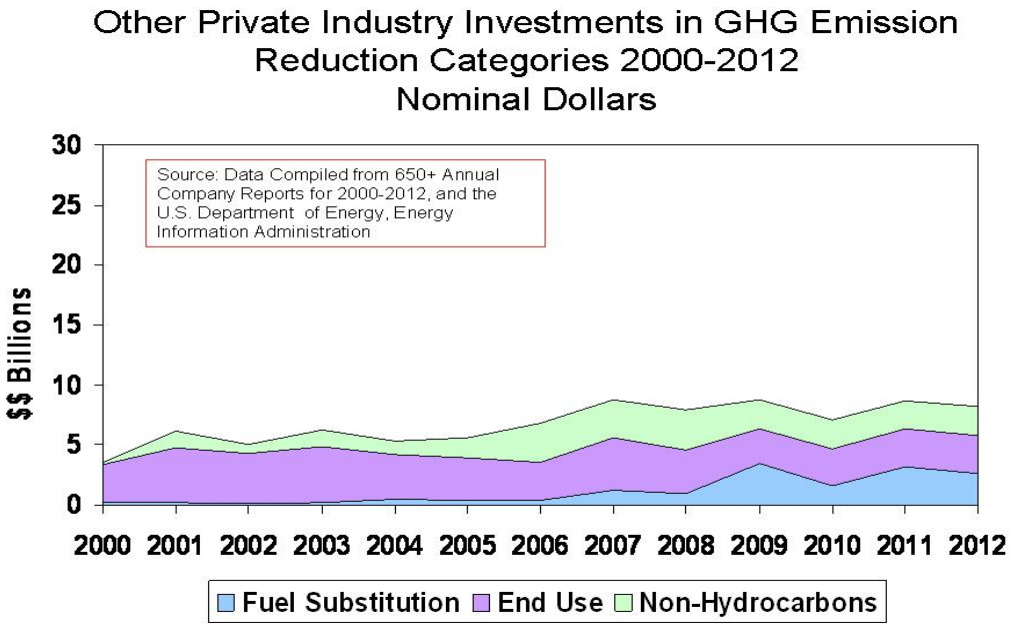

Other Private Industry Investments in GHG Emission Reduction Categories 2000-2012
Nominal Dollars
Source: Data Compiled from 650+ Annual Company Reports for 2000-2012, and the U.S. Department of Energy, Energy Information Administration
$$ Billions
30
25
20
15
10
5
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
Fuel Substitution
End Use
Non-Hydrocarbons

Figure A-7

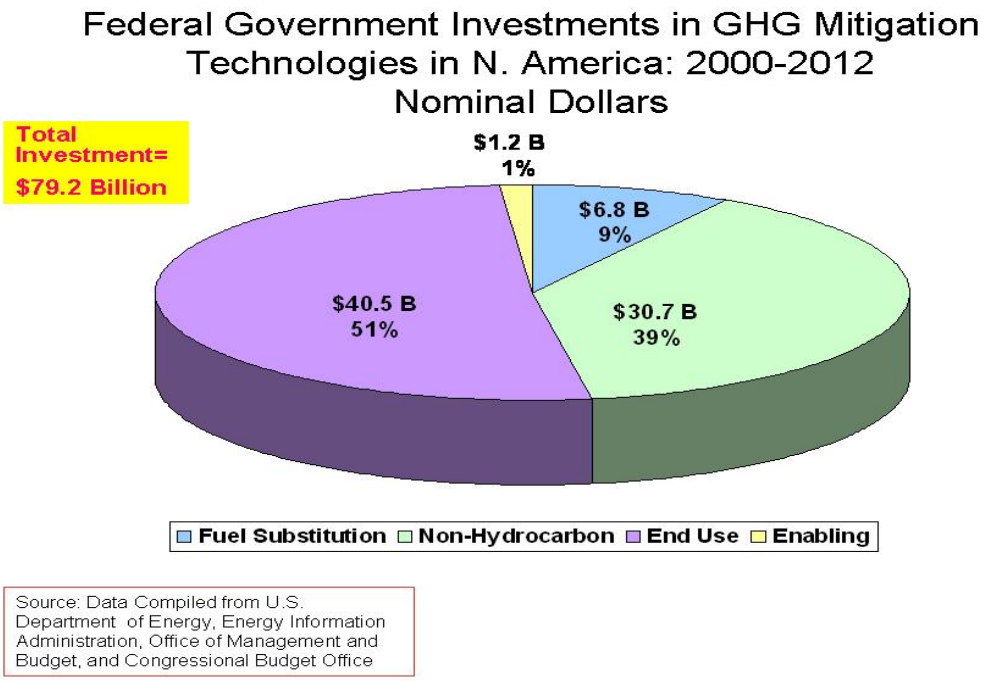


Figure A-8

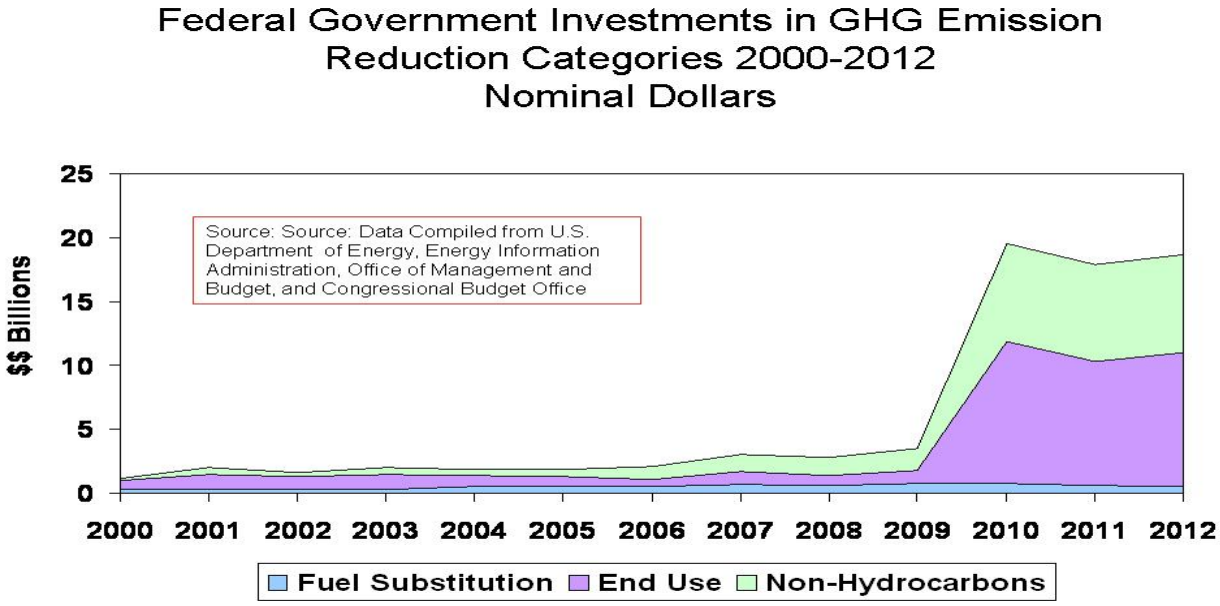


Figure A-9

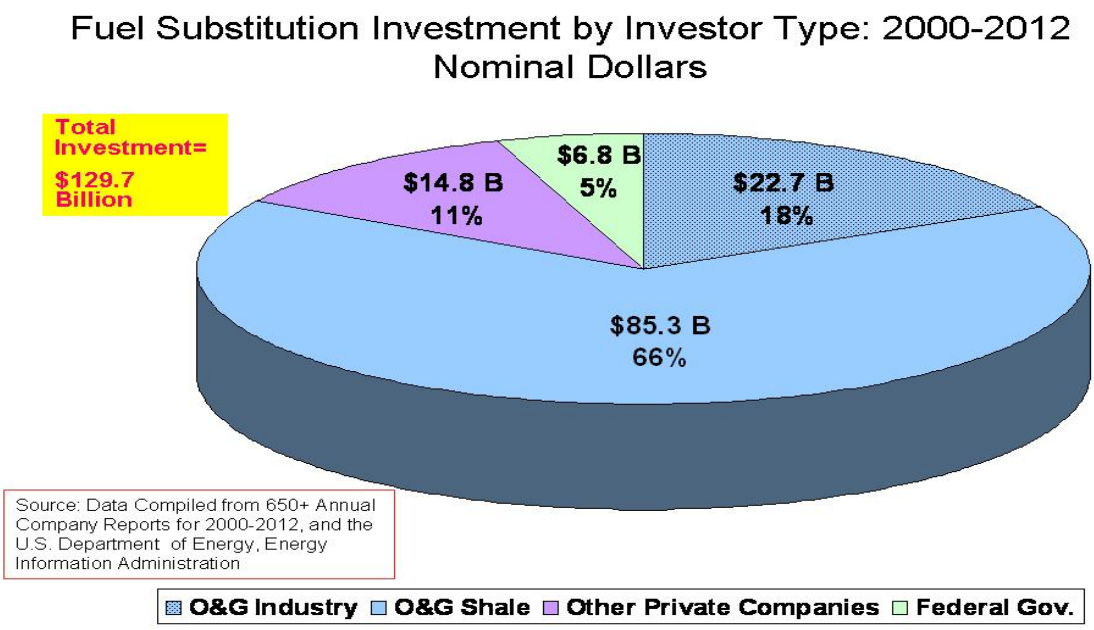


Figure A-10

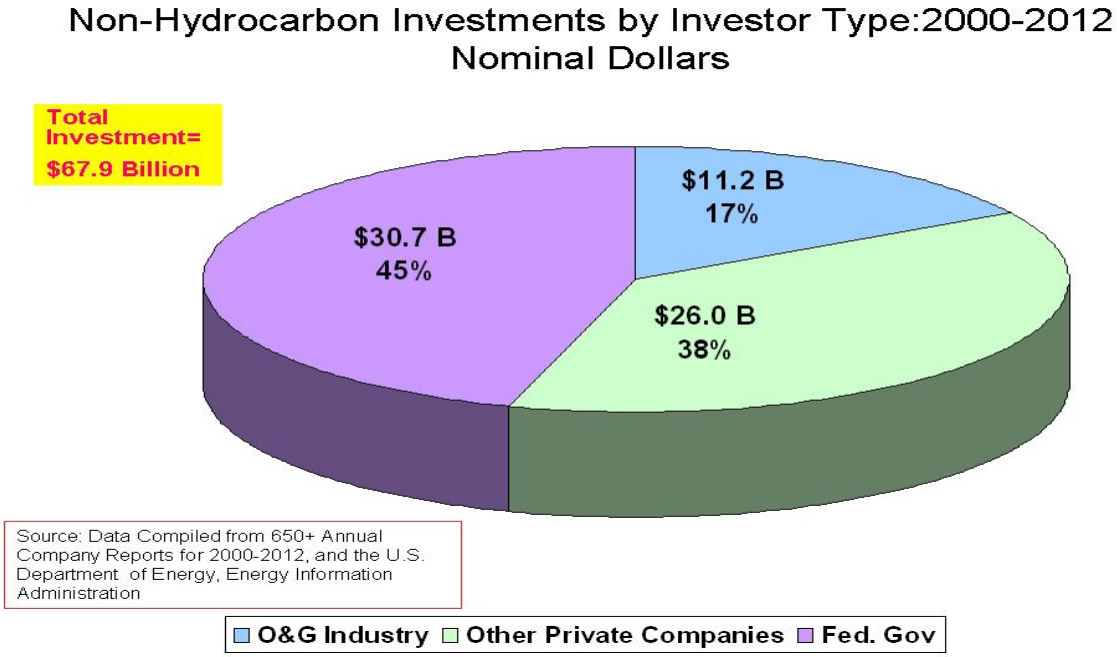
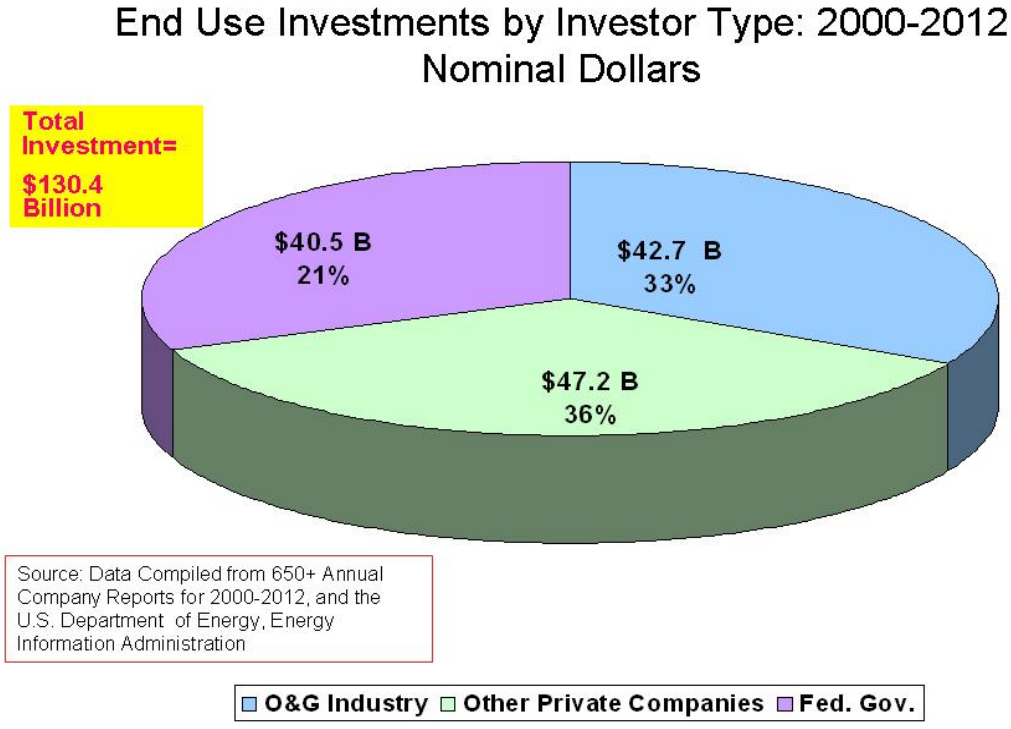


Figure A-11


End Use Investments by Investor Type: 2000-2012
Nominal Dollars
Total Investment= $130.4 Billion
$40.5 B
21%
$42.7 B
33%
$47.2 B
36%
Source: Data Compiled from 650+ Annual Company Reports for 2000-2012, and the U.S. Department of Energy, Energy Information Administration
O&G Industry
Other Private Companies
Fed. Gov.

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