U.S. CARBON DIOXIDE EMISSIONS AND INTENSITIES OVER TIME: A DETAILED ACCOUNTING OF INDUSTRIES, GOVERNMENT AND HOUSEHOLDS

Prepared by the
U.S. Department of Commerce
Economics and Statistics Administration

April 2010

Acknowledgements

I would like to acknowledge the contributions of those who assisted in the preparation of this report.

I am particularly grateful for the work done by members of my staff. David Henry performed the bulk of the analytic work that went into the preparation of this report. He was assisted by Beethika Khan and Sandra Cooke-Hull. Mark Doms, Chief Economist at the Department of Commerce, supervised the work.

We appreciate the help from our Commerce colleagues at the Bureau of the Census, the Bureau of Economic Analysis and the International Trade Administration.

My staff and I are also grateful for the comments and suggestions from our colleagues at other agencies and organizations. We are particularly grateful to the Energy Information Administration as both the primary source of the data used to create our detailed estimates and the personal guidance they provided during the course of our analysis. In addition, I want to personally thank Jeff Werling, President of the University of Maryland's Inforum research group for his direct involvement in the development and completion of the analysis. We have also benefited greatly from comments and advice from the Council of Economic Advisers, the Environmental Protection Agency, Department of Energy, the Department of the Treasury, and the Congressional Budget Office. Their astute observations greatly enhanced our work.

Finally, I would like to express my appreciation to the staff of the Council on Environmental Quality for their excellent comments and for their interest in this work.

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EXECUTIVE SUMMARY

Greenhouse gas emissions have increased markedly since the pre-industrial era and are increasing at such a rate that their concentration in the atmosphere is producing a warming influence on the global climate. In order to make well-informed decisions on ways to reduce greenhouse gas emissions, it is important to understand how the different economic sectors contribute to the production of greenhouse gases, which sectors are relatively carbon dioxide (CO_2) intensive, and how these patterns have evolved over time. To that end, this report analyzes energy-related CO_2 emissions and intensities for 349 industries, Government (Federal, state and local), and Households for the 1998 to 2006 period. The 349 industries cover the entire economy, providing information on detailed subsectors within the aggregate sectors of Agriculture, Forestry and Fisheries, Mining, Construction, Manufacturing, Transportation Services, and All Other Services. CO_2 intensities for industries and Government refer to the emissions produced per billion dollars of output. CO_2 intensities for Households are measured by emissions per thousand households.

The primary findings of the report are as follows:

- A large number of industries in the U.S. have seen declines in emissions intensity (that is, gains in emissions efficiency) over the past decade. These improvements at the industry level have contributed significantly to the overall pattern of greater emissions efficiency in the economy.
    - Energy-related CO_2 emissions in the U.S. increased more slowly than overall output growth during 1997 to 2007, indicating that the CO_2 intensity of the economy declined.
    - If not for these improvements in emissions efficiency, we estimate that CO_2 emissions in the U.S. would have been about 25 percent higher than actual emissions in 2007.
- The Manufacturing sector is often the focus of discussion about pollution control.
    - Manufacturing was responsible for about one-quarter of total CO_2 emissions in 2006, down from 30 percent in 1998. It reduced its CO_2 intensity over the 1998 to 2006 period.
    - The level of CO_2 output as well as the gain in efficiency varies significantly within the Manufacturing sector. For example, between 1998 and 2006, Chemicals had a significant emissions efficiency gain, while Nonmetallic Mineral Products had an efficiency loss.
- The Transportation Services sector, which accounts for about 15 percent of total emissions in the U.S., increased its emissions and showed only slight gains in emissions efficiency.

- The Household sector, accounting for almost a third of total emissions, was the largest emitter of energy-related CO_2 by 2006. Household emissions levels and intensities both increased between 1998 and 2006.
    - While emissions per household are low, the large number of households makes the cumulative effect of the Household sector a significant factor in total emissions.
    - Heat and power in residential structures accounted for about two-thirds of total Household emissions, whereas Household transportation accounted for the remainder. Emissions intensity related to Household transportation increased faster than that related to heat and power.
    - Household emission intensity is expected to have improved between 2006 and 2010.
- In addition to direct emissions, this report provides the total carbon footprint of industries by estimating indirect emissions (emissions associated with inputs that are purchased from other industries).
    - Indirect emissions occur both domestically and abroad since many inputs to production are imported from foreign trading partners.
    - According to our estimates, emissions associated with total imports are a small fraction of total U.S. emissions.

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I. INTRODUCTION

According to the Intergovernmental Panel on Climate Change (IPCC), greenhouse gas emissions have increased markedly as a result of human activity since the pre-industrial era, and are increasing at such a rate that their concentration in the atmosphere has a warming influence on the global climate (Intergovernmental Panel on Climate Change, 2007). A number of studies have focused on the economic consequences of such warming. For instance, the Natural Resources Defense Council (2008) projects that by the year 2100, the cost of climate change to the U.S. will amount to an annual reduction in real GDP of 3.6 percent per year.

In order to make informed decisions about how best to curb future greenhouse gas emissions, policy makers and the public need high quality data on:

- which sectors of the economy are responsible for the production of greenhouse gases;
- how this sectoral contribution has changed over time;
- which sectors have shown the greatest changes in their greenhouse gases relative to their output; and
- how output change in one sector of the economy affects emissions not only in that sector but (through input purchases) in other sectors as well.

To assist in answering these questions, this report quantifies the trends in energy-related CO_2 emissions for 349 industries, the Government, and Households. Energy is used by industries, Government and Households as a fuel for heat and power. Some industries also use energy as a direct input to production (commonly called a "feedstock"), such as natural gas used in the production of Fertilizer. Energy-related CO_2 emissions result from both these sources; however, the emissions attributable to heat and power comprise the majority of energy-related CO_2 emissions. In addition, a small number of industries (such as Lime and Cement) emit CO_2 because of the chemistry of the production process itself. These emissions are often referred to as non-energy process emissions. Our energy-related CO_2 emission measures by sector include all three channels (that is, the two energy-related channels plus the non-energy process emissions).

The main reason for focusing on energy-related CO_2 emissions is that they are the primary source of greenhouse gases. In 2007, energy-related CO_2 emissions comprised 81 percent of all greenhouse gas emissions in the U.S. Just over 1 percentage point of these CO_2 emissions were non-energy related process emissions (U.S. Energy Information Administration, 2010(a)).[1]

[1]The remaining greenhouse gas emissions came from methane (10 percent), nitrous oxide (5 percent) and man-made gases (4 percent) (U.S. Energy Information Administration, 2010(a)) whose emissions are quantified as CO_2 equivalents. We don't include these in our analysis.

Additionally, for each sector, this report provides energy-related CO_2 emissions per dollar of real (inflation-adjusted) gross output that the sector produces, a measure referred to as "CO_2 intensity."[2] If a sector's output is growing more rapidly than its CO_2 emissions, then CO_2 intensity is falling even though overall emissions levels may be rising. The distinction between CO_2 emission levels and CO_2 emissions intensity is important --- emissions refer to the total amount of CO_2 emitted into the earth's atmosphere, while CO_2 intensity is the ratio of CO_2 emitted to total (or sector) output. This distinction appears in recent climate change discussions when developing countries emphasize reducing their CO_2 intensity while the industrialized countries emphasize the level of CO_2 emissions (Eilperin, 2009). For the broad sectors of the economy, we estimate how much of the change in total emissions is driven by changes in emissions intensity over time.

In addition to looking at direct emissions from each sector, we also estimate the "total carbon footprint" for each of the sectors. The total carbon footprint includes both the direct energy-related and process emissions generated in the sector, and the indirect energy-related emissions which are imbedded in the inputs that the sector purchases. Through some simplifying assumptions, we can also distinguish an estimate for the indirect emissions associated with imported inputs. We use an economic input-output framework to determine total and indirect emissions.

This report contributes to the existing literature on greenhouse gases by reporting CO_2 emissions and CO_2 intensities over time by detailed industry sectors across the entire U.S. economy. There are some published measures of detailed CO_2 emissions, but only for Manufacturing. Other studies have estimated emissions across the economy, but not at the level of detail presented here. Finally, this paper reports consistent emissions levels and intensities for three years: 1998, 2002 and 2006. The availability of data across time facilitates the understanding of emission trends over time by industry.[3]

The next section of this report presents information on CO_2 emissions and intensity for the entire U.S. economy between 1997 and 2007. The third section describes how we construct industry-level energy-related CO_2 emissions and intensity data (an on-line technical appendix provides greater detail which is available at http://www.esa.doc.gov/CO2/Appendix/). The fourth section uses these data to illustrate the broad patterns of CO_2 emissions and intensities over time in major sectors of the U.S. economy, both in aggregate and by detailed industry sectors. The fifth section uses an input-output economic approach to estimate the indirect CO_2 emissions generated by industry and government activity. Taken together, indirect and direct emissions provide a

[2]Ostensibly, real output in constant price terms should grow at the same rate as physical output. Both are supposed to be a measure of production volume. In some relatively homogeneous sectors such as Steel, Cement, and Lime, physical output in tons might be a better denominator. Nonetheless, since most sectors are a mix of heterogeneous and rapidly changing products, real gross output was used.

[3] There are few published reports of CO_2 emissions by industry available and the majority of these reports are focused on the Manufacturing sector. The two earliest studies provide aggregate and some detailed emission estimates for Manufacturing in 1998 and 2002 (Schipper, 2006 and U.S. Environmental Protection Agency, 2008). Another study, released by the EPA in response to a recent Senate request on climate change policy, provides 2006 emission estimates for 42 Manufacturing sectors (U.S. Environmental Protection Agency, 2009). Finally, a Resources for the Future study provides estimates of carbon intensity for 34 Manufacturing industries, 18 Service sectors and the Government sector for 2002 (Ho, *et al.*, 2008).

picture of each industry's total carbon footprint. The final section provides conclusions drawn from this analysis.

II. CO_2 EMISSIONS AND CO_2 INTENSITY IN THE U.S. ECONOMY

The total energy-related CO_2 emissions in the U.S. increased from about 5.6 billion metric tons (Bmt) in 1997 to almost 6.0 Bmt in 2007, an increase of 7.4 percent over the decade or an average annual increase of about 0.7 percent per year. Figure 1 shows the pattern of emission increases over these years. Emissions peaked at the end of the economic expansion in 2000, fell during the recession of 2001, and then increased again as the economy expanded. Emissions have grown less since the mid-2000s.

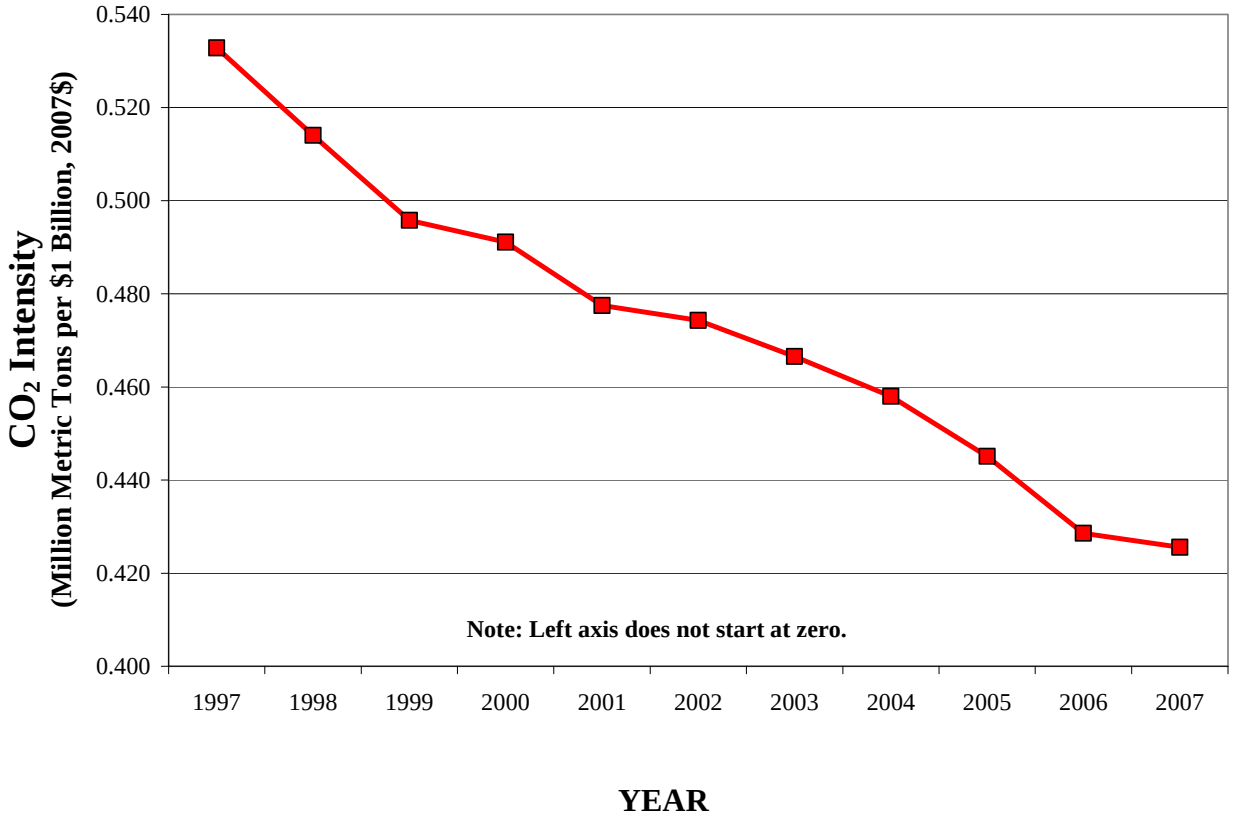
Figure 1. U.S. Energy-Related CO_2 Emissions 1997 - 2007

Source: U.S. Energy Information Administration, 2010(c).

The increase in total CO_2 emissions shown in Figure 1 is the net result of two offsetting factors. First, CO_2 emissions were increasing because the economy grew during this period, and increases in output usually require increases in energy consumption. Second, the economy was becoming more CO_2 efficient. During the 1997 to 2007 period, output as measured by Gross Domestic Product (GDP) rose in real (i.e. inflation adjusted) terms from $10.5 trillion to $14.1 trillion (in 2007$), an increase of 34 percent or about 3 percent

per year. CO_2 emissions rose by only 7.4 percent. This implies that aggregate CO_2 intensity fell and the economy produced fewer emissions for every dollar of output in 2007 than in 1997. Figure 2 shows that CO_2 intensity has steadily fallen from 0.533 million metric tons (Mmt) per $1 billion (in real 2007$) of output in 1997 to 0.426 Mmt in 2007, an overall decline of 20.1 percent and an average annual decline of 2.2 percent.[4]

Figure 2. CO_2 Intensity: CO_2 Emissions per $1 Billion of U.S. Real GDP 1997 - 2007



Source: U.S. Energy Information Administration, 2010(c), U.S. Bureau of Economic Analysis, 2010(a) and 2010(b), and ESA Calculations.

To emphasize the importance of increased emissions efficiency in the U.S. economy, we calculate that CO_2 emissions would have been 7.5 Bmt in 2007 if CO_2 intensity were as high in 2007 as in 1997. In reality, CO_2 emissions were lower, at 6.0 Bmt. Hence, absent the reductions in CO_2 intensity, emissions in the U.S. would have been 25 percent higher in 2007. Although CO_2 emissions rose in the U.S., they rose much more slowly than they would have if we had not made significant strides toward increased emissions efficiency,

[4]Emissions intensity is defined by the amount of emissions per dollar of real output. Energy intensity is defined by energy consumption per dollar of real output. Energy efficiency of the economy, i.e. the reduction in energy intensity, improved during the 1997-2007 period as well. Defined as energy consumption (in quadrillion Btus) per $1 billion of GDP, energy efficiency saw an average annual increase of about 2.2% during this period (ESA calculations from U.S. Energy Information Administration, 2010(g), energy consumption data).

either as a result of efficiency gains at the industry level or recomposition of the economy toward lower emissions-intense sectors.

III. DATA AND METHODS FOR MEASURING CO_2 EMISSIONS AND CO_2 INTENSITY

Figures 1 and 2 show economy-wide trends. Underlying these broad national data are substantially different trends in CO_2 emissions and intensities across economic sectors. This section describes the data and methods we use to look at CO_2 usage within sectors. For a more detailed explanation of how the energy-related CO_2 measures and intensities are compiled, see the online detailed appendix to this report (available at http://www.esa.doc.gov/CO2/Appendix/).

Our estimates of CO_2 emissions and intensities by industry are done in three basic steps, and are consistent with published CO_2 emissions by industry, where available. First, for the years 1998, 2002, and 2006, energy use data in physical units by fuel type are developed for a set of approximately 120 economic sectors from a variety of data sources. Second, we multiply energy use by CO_2 conversion factors for each fuel type in order to yield estimates of CO_2 emissions by industry sector, the Government, and Households (see U.S. Energy Information Agency, 2010(b) for CO_2 conversion factors). Third, we allocate the CO_2 emissions from these 120 industry sectors (including estimates for both aggregate and detailed industries) to 349 specific industries, the Government, and Households. This allocation is done using energy use data drawn from Inforum's Inter-industry Large-scale Integrated and Dynamic (Iliad) model, an inter-industry (input-output) based model, developed and maintained by Inforum, a research group within the Department of Economics at the University of Maryland.[5]

The Energy Information Administration (EIA) is the primary source for aggregate and detailed estimates on energy use. The EIA also contributes to the Environmental Protection Agency's (EPA's) official reporting on greenhouse gas emissions, including CO_2. In our analysis, the primary data used to estimate emissions were from the EIA. In addition to their aggregate emissions data, this report uses data for the Manufacturing sector from EIA's Manufacturing Energy Consumption Survey or MECS (U.S. Energy Information Administration, 2010(d));[6] Commercial Building Energy Consumption Survey

[5] The Iliad model database provides a consistent underlying database for real and nominal gross output, imports and exports by industry over time. Its data and structure include a detailed time-series of input-output tables in real terms that are used here to (1) allocate the published estimates on carbon emissions that are available at aggregated levels across a more detailed set of sectors and (2) compute the total and indirect energy and emissions requirements for each of the 349 sectors. Industry definitions are consistent with the 2002 North American Industry Classification System (NAICS) of the United States. See University of Maryland (2010) for more details.

[6] MECS provides enough energy consumption detail to estimate the emissions for larger categories and for some subcategories; we must create estimates for other subcategories. As an example, MECS has energy information for the larger Food Products category, and within Food Products, for Wet Corn Milling and for Sugar Manufacturing. However, there is not enough detail in the MECS to make estimates for emissions of other subsectors within Food Products such as Dairy or Bakery Products. In order to estimate emissions for these subsectors, we first calculated emissions for Food Products less emissions for Wet Corn Milling and Sugar Manufacturing. Then we used energy consumption by type of fuel by industry in the Iliad input-output tables to spread the residual to subcategories of Food Products not directly captured by MECS.

or CBECS (U.S. Energy Information Administration, 2010(e)); and EIA's report on Manufacturing CO_2 emissions (Schipper, 2006). Results from EIA's National Energy Modeling System or NEMS (U.S. Energy Information Administration, 2010(f)) are used to make emissions estimates for Transportation. The reason why 1998, 2002 and 2006 are chosen as benchmark years for this analysis is that these are survey years for the MECS. All other estimates are re-benchmarked, as necessary, to conform to these years.

Another notable data source used in our analysis includes emissions estimates from the Environmental Protection Agency (Environmental Protection Agency, 2008). Our analysis also relies on real output, trade and other data from the U.S. Bureau of the Census and Bureau of Economic Analysis (see the online detailed appendix for details which is available at http://www.esa.doc.gov/CO2/Appendix/).

Finally, the estimates of emissions by industry are made consistent with annual total emissions published by the EIA. It is important to understand that in this analysis, as in the EIA emissions data, all energy consumption and production by Electric and Natural Gas Utilities and their corresponding CO_2 emissions are allocated as emissions to the end users, whether they are industries, Government or Households. In other words, there are no separate emissions estimates provided here for the Electric and Natural Gas Utility sectors.[7]

Once CO_2 emissions are estimated for each sector and each year, we estimate CO_2 intensity as total CO_2 emissions divided by a measure of output in each sector. For industries and the Government, we use gross output in real dollars (i.e., shipments or revenues plus inventory changes) from the Iliad model and its databases. The Iliad gross output data are largely derived from data reported by the Bureau of Economic Analysis (U.S. Bureau of Economic Analysis, 2010 (c) and 2010 (d)). The reason why gross output is used in this study instead of value added is that value added is only available for 55 industries in the Iliad database whereas gross output is available for all 349 industries and the Government sector.

The remaining sector of the economy for which we examine energy-related CO_2 emissions is Households. As the concept of "production" for Households is quite different than that for industries, CO_2 intensity is computed by dividing total energy-related CO_2 emissions by the number of households (in thousands), as reported by the Census Bureau (U.S. Bureau of the Census, 1998, 2010(a), 2010(b)). As a consequence, it is not possible to compare the level of CO_2 intensity between Households and industries since they are in different units.

The full set of data on 349 industries, the Government sector and the Household sector is available at the online appendix (which is available at http://www.esa.doc.gov/CO2/Appendix/). The list of the 349 industries for which data are available is at the end of this report, as an attachment. The remainder of this report focuses on trends and results that emerge from looking at energy emissions in some of the larger economic sectors and a few selected subsectors.

[7]The emissions generated by the utilities themselves have also been passed along to the end users, consistent with EIA allocations. In addition, emissions from Water, Sewage, and Other Systems (NAICS 2213) have not been estimated.

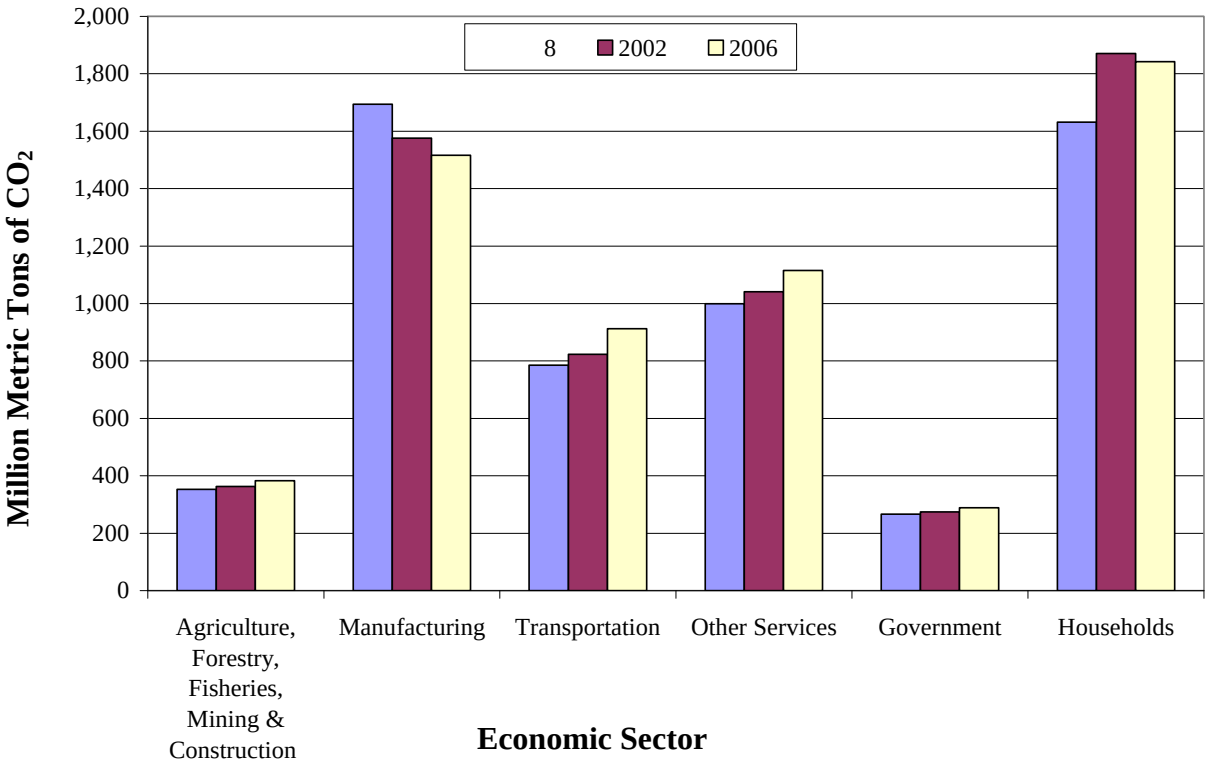
IV. TRENDS IN CO_2 EMISSIONS AND CO_2 INTENSITY ACROSS BROAD ECONOMIC SECTORS

This section of the report presents CO_2 emissions and CO_2 intensities for the following six aggregate economic sectors that together comprise the entire economy:

- A composite sector of the Agriculture, Forestry, Fisheries, Mining and Construction industries;
- Manufacturing;
- Transportation Services;
- Other Services;
- Government; and
- Households.

Figure 3 shows total direct CO_2 emissions for each of these sectors in 1998, 2002 and 2006. The Transportation sector had the largest proportional increase in CO_2 emissions over the 1998-2006 period, posting an increase of 16.1 percent, or 127 million metric tons (Mmt). Households posted the largest absolute increase with a net gain of 210 Mmt (a 12.9 percent jump) which accounted for almost two-thirds of the 328 Mmt increase within the entire economy. In 2006, the Household sector was the largest producer of energy-related CO_2 emissions. About 45 percent of the increase in Household CO_2 came from an increase in gasoline usage while the remaining 55 percent arose from higher utility usage.

Figure 3. Total CO_2 Emissions by Economic Sector: 1998, 2002 and 2006

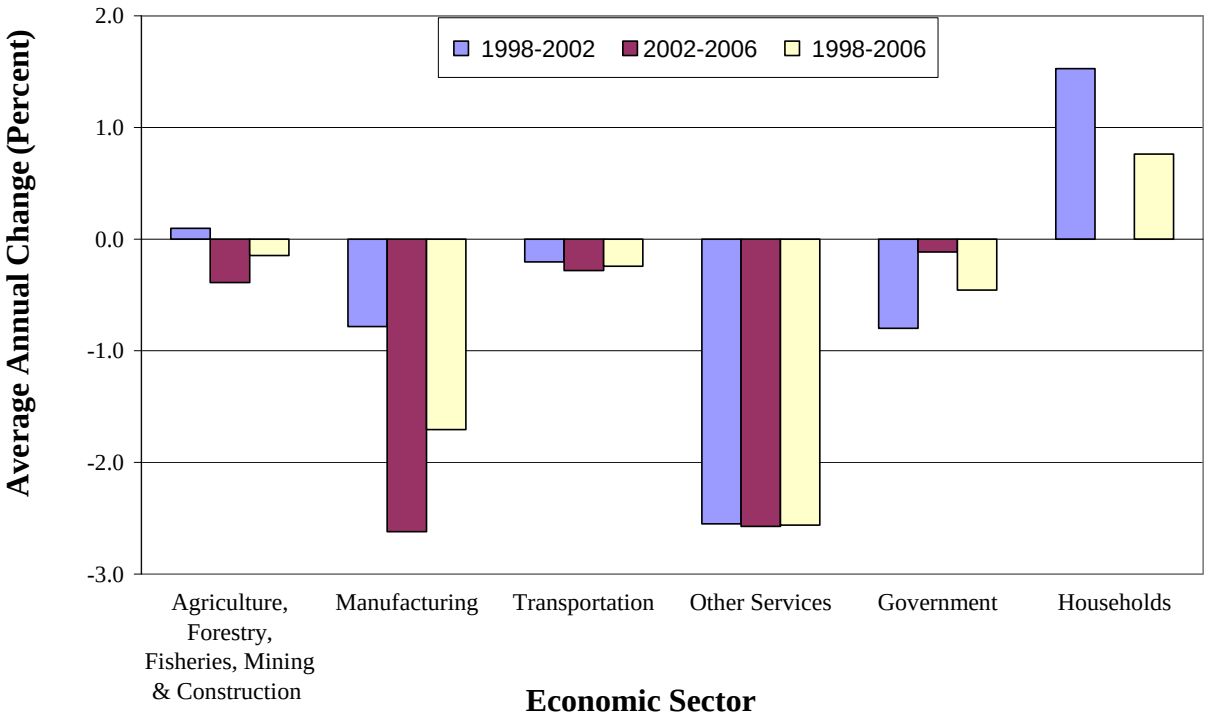


Source: Appendix Tables A-61,A-62 and A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

An interesting story is apparent in the Manufacturing sector. Manufacturing is responsible for a significant portion of energy-related CO_2 emissions and this sector displayed a 10.5 percent drop in total CO_2 emissions from 1998 to 2006. As a result, Manufacturing's share of total CO_2 emissions dropped from 30 percent to 25 percent between 1998 and 2006. Manufacturing industries, whose share of the economy declined by 3 percentage points between 1998 and 2006, demonstrated a greater decline (5 percentage points) in its share of emissions.

Figure 4 shows the change in CO_2 emissions intensity during 1998 to 2006, as well as two sub-periods 1998-2002 and 2002-2006. Between 1998 and 2006, the Other Services sector had the largest gain in emissions efficiency with an annual average decline of 2.3 percent per year in CO_2 intensity. The Other Services sector was followed by Manufacturing where intensity declined at an average annual pace of 1.7 percent. The other four sectors showed much smaller declines or, as was the case for Households, a small increase in CO_2 intensity.[8] However, as will be demonstrated later in this paper, not all Manufacturing industries showed the same degree of progress in becoming more emissions efficient.

Figure 4. Change in CO_2 Emissions per $1 Billion of Output by Economic Sector: 1998 - 2002, 2002 – 2006, and 1998 - 2006



Source: Appendix Tables A-61, A-62 and A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

The results in Figures 3 and 4 can be used to investigate how changes in emissions intensity in each of these six major sectors impact the level of aggregate emissions. More

[8]This result for the Household sector holds when the intensity calculations are based on a per-capita basis as well as a per-household basis.

specifically, total CO_2 emissions can change for two reasons. The first is that CO_2 intensity can change within each economic sector. For example, if every sector starts emitting less CO_2 per unit of output, then aggregate emissions levels would decline, all else equal. The second reason is that each sector can grow (or shrink). If a very CO_2-intensive sector of the economy grows more slowly than other sectors, then overall CO_2 emissions in the economy will not rise as quickly.

Table 1 shows one approach to estimating the relative importance of changes in CO_2 intensity within broad economic sectors to changes in aggregate emissions. In order to do this calculation, for each sector we hold the level of CO_2 intensity between 1998 and 2006 constant at its 1998 level, and then estimate what total emissions level would have been in 2006 if output in each sector grew at its actual pace. The first two columns of Table 1 show actual CO_2 intensity for 1998 and 2006, and columns (3) and (4) show the actual CO_2 emissions level for each broad economic sector. Column (5) shows the actual percent change in CO_2 emissions while column (6) shows the percent change in emissions if CO_2 intensity had remained at its 1998 level while output grew at its actual pace.

Table 1. Decomposing Total Emissions Changes, 1998 to 2006

Economic Sector	CO_2 Intensity: Emission per $1 Billion in Output		Actual CO_2 Emissions (Mmt)		Percent Change in Emissions 1998 - 2006	
	1998 (1)	2006 (2)	1998 (3)	2006 (4)	Actual (5)	Simulated Holding Emissions Intensity Constant at 1998 Level (6)
Agriculture, Forestry, Fisheries, Mining, and Construction	0.258	0.255	352.4	382.8	8.6%	9.9%
Manufacturing	0.420	0.366	1,693.8	1,516.2	-10.5%	2.6%
Transportation	1.351	1.325	785.5	912.1	16.1%	18.4%
Other Services	0.112	0.091	999.0	1,114.9	11.6%	37.6%
Government	0.222	0.214	266.8	288.9	8.3%	12.7%
Households	0.016*	0.017*	1,631.2	1,841.5	12.9%	9.5%
Total Economy	n.a.**	n.a.**	5,728.7	6,056.7	5.7%	13.8%

*Mmt of CO_2 per thousand households; **n.a. since the CO_2 intensities presented here are based on a mix of Mmt per output in 2000$ and Mmt per thousand households, and as a result, the Household estimate is not directly comparable to that for the rest of the economic sectors. CO_2 intensities in Figure 2 are based on Mmt per "value added," not output, and are therefore not comparable the CO_2 intensities in Table 1.
Source: Appendix Tables A-61 and A-63(available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

As shown in the last row of the table, actual CO_2 emissions rose by 5.7 percent (328 Mmt), whereas the simulated increase was 13.8 percent (460 Mmt), suggesting that reductions in CO_2 intensity played an important role in reducing the growth in emissions. Given the results in Figure 4, it is not surprising that most of these reductions occurred because of decreasing emissions intensity in Manufacturing and in Other Services. The Manufacturing sector saw a decline of 10.5 percent in its emissions between 1998 and 2006. If the emissions intensity in Manufacturing had not improved during this period,

emissions would have increased by 2.6 percent. The Other Services sector of the economy saw a rise in its emissions of 11.6 percent, whereas the rise would have been more than three times as large (37.6 percent) if its emissions intensity had remained at the 1998 level.

It is important to understand that CO_2 intensity levels should not be compared across industries. CO_2 intensity for an industry is calculated by dividing the total amount of emissions resulting from that industry by the industry's real output. As a result, an industry with a high value of real output can appear to be a low CO_2-intense sector relative to an industry with lower output value, even if the two industries have similar levels of total emissions. While it is helpful to compare changes in intensities across sectors over time, it is not appropriate to compare absolute levels of emission intensities at a point in time across sectors.[9]

We now turn to a more detailed discussion of changing emissions patterns in several of these aggregate economic sectors. More specifically, we look at emissions from:

- all twenty-one 3-digit NAICS industries in the Manufacturing sector;
- all twenty-one 6-digit NAICS industries in the Chemical sector (a subsector of Manufacturing);
- all ten 3-digit NAICS industries in the Transportation sector;
- the Government sector; and
- the Household sector.

These provide a sample of the variation in emissions estimates and intensities that is to be found in the data. We have results for all of the 349 detailed industries in the online appendix, as well as the Government and Households (the detailed appendix is available at http://www.esa.doc.gov/CO2/Appendix/).

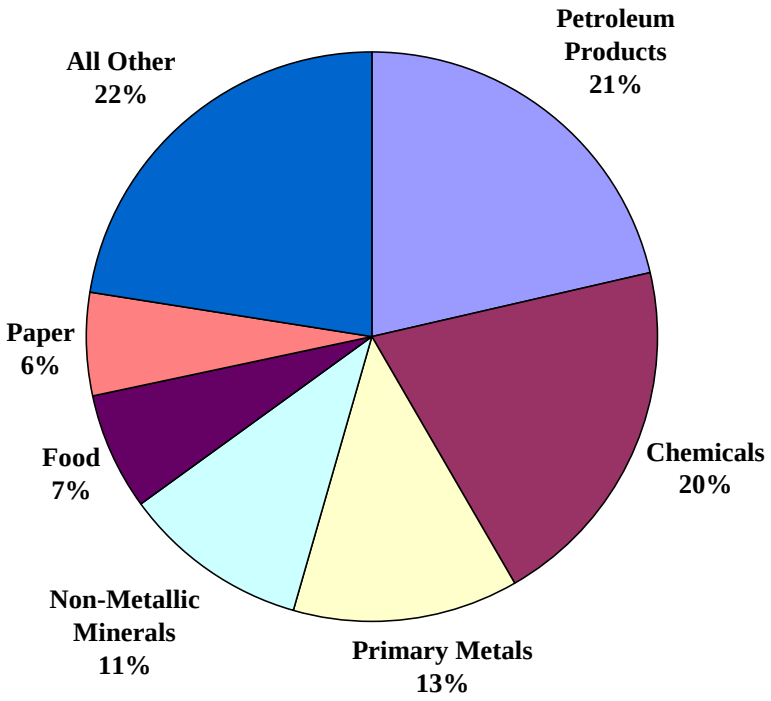
A. MANUFACTURING

As Figures 3 and 4 indicate, the Manufacturing sector has reduced its CO_2 output and intensity over the past decade. These changes in Manufacturing can be more thoroughly examined by looking at emissions data at a detailed industry level within Manufacturing. As we will see, the trends in CO_2 output and intensity vary considerably across Manufacturing industries.

Figure 5 shows the distribution of CO_2 emissions across seven detailed industry sectors within Manufacturing. According to Figure 5, over half of all Manufacturing CO_2 emissions in 2006 came from the Petroleum Products, Chemicals, and Primary Metals industries. Nonmetallic Mineral Products also contributed significantly to CO_2 emissions, mainly because of the production of Cement and Lime, which uses energy-intensive processes and which also have large process emissions.

[9] Our estimates of intensity include CO_2 only. If other greenhouse gases were added to the numerator, the levels and trends for some industries, such as Agriculture, Forestry, and Fisheries may be significantly different.

Figure 5. Distribution of Total CO_2 Emissions Within the Manufacturing Sector, 2006



Note: CO_2 emissions from the Manufacturing sector totaled 1,516.2 Mmt in 2006.
Source: See Appendix Table A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

Table 2 provides further details, showing emission intensities for each 3-digit NAICS Manufacturing industry for 1998, 2002 and 2006. Table 2 shows that the overall gain in emissions efficiency between 1998 and 2006 for Manufacturing was 1.7 percent per year (the average of a 0.8 percent gain per year between 1998 and 2002, and a 2.6 percent gain per year between 2002 and 2006).

Table 2 also shows that there is a wide variation in the changes in emission intensity across Manufacturing industries. Some of the Manufacturing industries with the greatest share of emissions in 2006 (Figure 5) such as Petroleum Products, Chemicals, Primary Metals, and Paper had significant improvements in their emissions efficiency. On the other hand, Non-metallic Mineral Products, Food, and Textile Mills showed no or minimal efficiency gains between 1998 and 2006.

Table 2. CO_2 Intensity Levels and Average Annual Change in Manufacturing Industries: 1998, 2002 and 2006

Industry Title (NAICS)	CO_2 Intensity (Mmt CO_2/$1 billion Output (2000$)) 1998	2002	2006	Average Annual Change 98-02	02-06
Total Manufacturing Sector (31-33)	0.420	0.407	0.366	-0.8%	-2.6%
Food (311)	0.210	0.223	0.221	1.5%	-0.2%
Beverage and Tobacco Products (312)	0.069	0.079	0.083	3.7%	1.2%
Textile Mills (313)	0.578	0.606	0.662	1.2%	2.2%
Textile Mill Products (314)	0.173	0.156	0.139	-2.5%	-3.0%
Apparel (315)	0.090	0.081	0.088	-2.6%	1.9%
Leather and Allied products (316)	0.100	0.120	0.072	4.8%	-12.1%
Wood Products (321)	0.225	0.208	0.258	-1.9%	5.5%
Paper (322)	0.749	0.687	0.608	-2.1%	-3.0%
Printing and Related Support (323)	0.135	0.142	0.145	1.4%	0.5%
Petroleum and Coal Products (324)	1.441	1.263	1.210	-3.2%	-1.1%
Chemicals (325)	0.892	0.823	0.619	-2.0%	-6.9%
Plastic and Rubber Products (326)	0.275	0.257	0.279	-1.7%	2.0%
Nonmetallic Mineral Products (327)	1.550	1.641	1.613	1.4%	-0.4%
Primary Metals (331)	1.338	1.298	1.054	-0.8%	-5.1%
Fabricated Metal Products (332)	0.203	0.189	0.188	-1.8%	-0.1%
Machinery (333)	0.112	0.109	0.122	-0.8%	2.9%
Computer and Electronic Products (334)	0.098	0.105	0.080	1.5%	-6.4%
Electrical Equip., Appliances, and Components (335)	0.138	0.174	0.146	5.9%	-4.3%
Transportation Equipment (336)	0.100	0.086	0.100	-3.7%	3.8%
Furniture and Related Products (337)	0.120	0.102	0.121	-4.1%	4.5%
Miscellaneous Manufacturing (339)	0.106	0.080	0.073	-6.8%	-2.4%

Source: Appendix Tables A-61, A-62 and A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

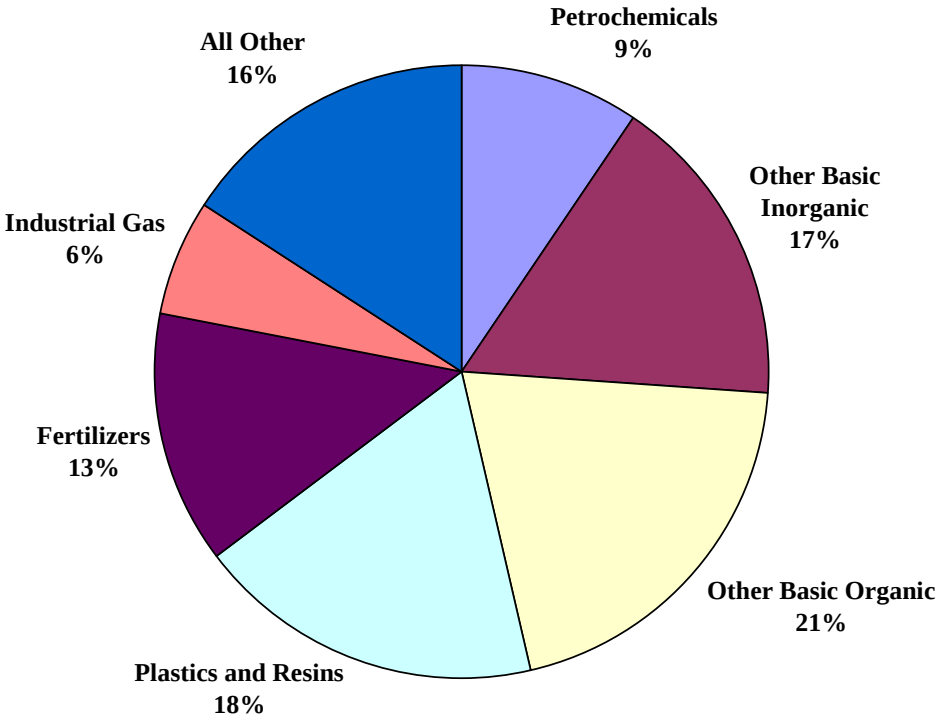
Note that CO_2 emissions in Manufacturing can change for two reasons. Table 1 investigated the first reason which is changes in CO_2 intensity within 3-digit NAICS Manufacturing industries. The second thing that can change overall emissions is that each sector within Manufacturing can grow (or shrink). For example, if there is a shift from high CO_2-intensive sectors to low CO_2-intensive sectors, then overall CO_2 emissions in Manufacturing will not rise as quickly. We performed a "shift-share" analysis, which is one approach to estimating the relative importance of both these reasons, and found that the emission intensity improvement between 1998 and 2006 in the overall Manufacturing sector resulted from the improved intensities in its subsectors, and not from a shift from high emissions-intense industries to lower emissions-intense industries.

Chemicals

This section provides further details on the Chemical industry which is a subsector of Manufacturing. The Chemical industry is one of the larger CO_2 emitters within Manufacturing, accounting for a fifth of total Manufacturing CO_2 emissions. However, with an emissions efficiency gain that is more than twice as large as that seen in overall Manufacturing, this sector has been highly successful in reducing its CO_2 intensity. As shown in Table 2, the overall improvement in emissions efficiency between 1998 and 2006 for Chemicals was 4.5 percent per year (the average of a 2.0 percent gain per year between 1998 and 2002, and a 6.9 percent gain per year between 2002 and 2006), compared to a 1.7 percent annual rate for all of Manufacturing. However, like Manufacturing, the trends in CO_2 output and intensity vary considerably within the Chemical sector.

Figure 6 shows the share of emissions from some of the specific industries within the Chemical sector. The industries which emit the most CO_2 within the Chemical sector include those industries that produce Other Basic Organic, and Other Basic Inorganic Chemicals, Plastics and Resins, and Fertilizers.

Figure 6. Distribution of Total CO_2 Emissions Within the Chemical Sector, 2006



Note: CO_2 emissions from the Chemical sector totaled 307.3 Mmt in 2006.
Source: Appendix Table A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

CO_2 intensities and their efficiency gains or losses are shown in Table 3 for the industries within the Chemical sector. Petrochemicals, Industrial Gas, and Fertilizer industries experienced consistent carbon efficiency gains since 1998. Other Basic Organic, and Other

Basic Inorganic Chemicals, and Plastics and Resins industries experienced mixed changes in their efficiency.

Table 3. CO_2 Intensity Levels and Average Annual Change in Chemical Industries: 1998, 2002 and 2006

Industry Title (NAICS)	CO_2 Intensity (Mmt CO_2/$1 billion of Output (2000$)) 1998	2002	2006	Average Annual Change 98-02	02-06
Total Chemical Sector (325)	0.892	0.823	0.619	-2.0%	-6.9%
Petrochemicals (325110)	1.424	1.224	0.759	-3.7%	-11.3%
Industrial Gas (325120)	4.522	3.169	2.743	-8.5%	-3.5%
Synthetic Dyes and Pigments (325130)	0.904	0.509	0.316	-13.4%	-11.2%
Other Basic Inorganic Chemicals (325180)	1.869	2.104	2.331	3.0%	2.6%
Other Basic Organic Chemicals (325190)	1.468	1.805	0.967	5.3%	-14.4%
Plastics Material and Resins (325211)	0.966	1.281	1.019	7.3%	-5.6%
Synthetic Rubber (325212)	0.572	0.521	0.559	-2.3%	1.8%
Cellulosic Organic Fibers (325221)	0.307	0.174	0.103	-13.2%	-12.3%
Noncellulosic Organic Fibers (325222)	0.576	0.524	0.707	-2.3%	7.8%
Fertilizers (325310)	3.788	3.715	3.530	-0.5%	-1.3%
Pesticide and Other Agricultural Chemicals (325320)	0.297	0.150	0.106	-15.7%	-8.3%
Pharmaceuticals and Medicines (325411-4)	0.097	0.088	0.067	-2.4%	-6.6%
Paints and Coatings (325510)	0.146	0.093	0.067	-10.7%	-7.9%
Adhesives (325520)	1.038	0.656	0.460	-10.8%	-8.5%
Soaps and Cleaners (325610)	0.510	0.361	0.255	-8.3%	-8.3%
Toiletries (325620)	0.180	0.148	0.100	-4.8%	-9.3%
Printing Ink (325910)	1.123	0.752	0.478	-9.5%	-10.7%
Explosives (325920)	0.418	0.053	0.016	-40.3%	-26.5%
Custom Compounding of Purchased Resins (325991)	0.351	0.193	0.140	-13.9%	-7.7%
Photographic Films and Chemicals (325992)	0.277	0.252	0.252	-2.3%	0.0%
Other Miscellaneous Chemical Products (325998)	0.986	0.663	0.463	-9.4%	-8.6%

Source: Appendix Tables A-61, A-62 and A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

Some of the Chemical industries such as Synthetic Dyes and Pigments, Cellulosic Organic Fibers, Pesticide and Other Agricultural Chemicals, Adhesives, Explosives, and Other Miscellaneous Chemical Products show very large emissions efficiency gains between 1998 and 2006. The dramatic shift in emissions intensity could have been driven by a number of factors including technology improvements along with shift in product mixes toward less carbon-intense products while at the same time shifting the production of carbon-intense inputs abroad.[10]

[10] Other reasons or combinations of reasons also may have driven the actual estimates. The reasons behind the level of emissions or emission intensities are not the focus of this study.

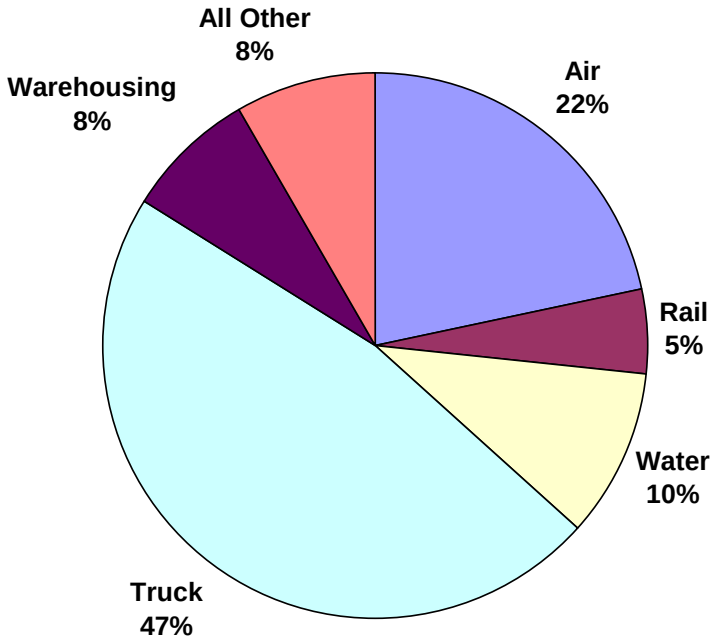
B. TRANSPORTATION SERVICES

In 2006, the Transportation Services sector was responsible for 15 percent of total CO_2 emissions. Over the period of analysis, the sector saw efficiency gains of 0.8 percent per year between 1998 and 2002; the trend, however, reversed during the 2002-2006 period when the sector experienced efficiency declines of 0.3 percent per year.

Although CO_2 intensity in Transportation rose between 2002 and 2006, CO_2 intensity was at a lower level in 2006 than in 1998, resulting in an overall efficiency gain of 0.2 percent per year between 1998 and 2006 (the average of a 0.8 percent gain per year between 1998 and 2002, and a 0.3 percent decline per year between 2002 and 2006). This suggests that the efficiency gains experienced between 1998 and 2002 were not entirely eroded between 2002 and 2006.

Figure 7 shows the distribution of emissions in the Transportation sector. By far, the greatest emitter of CO_2 within the Transportation sector was the Trucking industry.

Figure 7. Distribution of Total CO_2 Emissions Within the Transportation Sector, 2006



Note: CO_2 emissions from the Transportation sector totaled 912.1 Mmt in 2006.
Source: Appendix Table A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

Table 4 shows carbon intensities and efficiency gains for industries within the Transportation sector over the analysis period. The Water Transportation industry showed significant increases in emissions intensity between 1998 and 2006. Like Water, the Trucking sector also became less efficient over this time period. On the contrary, the Air Transportation, Rail Transportation and, in particular, the Warehousing and Storage industries demonstrated significant improvements in emissions efficiency.

Table 4. CO_2 Intensity Levels and Average Annual Change in Transportation Industries: 1998, 2002 and 2006

Industry Title (NAICS)	CO_2 Intensity (Mmt of CO_2/$1 billion of Output (2000$)) 1998	2002	2006	Average Annual Change 98-02	02-06
Total Transportation and Warehousing (48-49)	1.351	1.310	1.325	-0.8%	0.3%
Air Transportation (481)	1.692	1.744	1.581	0.8%	-2.4%
Rail Transportation (482)	0.856	0.744	0.731	-3.5%	-0.5%
Water Transportation (483)	2.791	3.075	3.768	2.5%	5.2%
Truck Transportation (484)	1.617	1.811	1.876	2.9%	0.9%
Transit and Ground Passenger Transportation (485)	0.583	0.636	0.681	2.2%	1.7%
Pipeline Transportation (486)	1.600	1.776	1.805	2.6%	0.4%
Support Activities for Transportation and Sightseeing (487-488)	0.045	0.022	0.025	-16.4%	2.7%
Couriers and Messengers (492)	0.112	0.081	0.087	-7.8%	1.8%
Warehousing and Storage (493)	2.128	1.523	1.323	-8.0%	-3.5%

Source: Appendix Tables A-61, A-62 and A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

C. GOVERNMENT

The Government sector—including Federal, state and local governments—accounts for about 5 percent of CO_2 emissions in the U.S. and this has changed little since 1998. The sector displayed some improvement in its CO_2 intensity between 1998 and 2002, but almost none between 2002 and 2006, as shown in Figure 4. In 2006, CO_2 emissions resulting from the Government, i.e. heat and power from public offices and fuel consumption of government vehicles (including aviation fuel for the military), were about 289 Mmt.[11]

D. HOUSEHOLDS

The Manufacturing and the Household sectors are the two highest-emitting sectors, as Figure 3 indicates. While Manufacturing has shown significant progress in reducing its CO_2 intensity over the past decade, Households have not. In 2006, Households directly accounted for about 30 percent of all CO_2 emissions. Emissions in the Household sector were estimated as the combined consumption of all primary fuels—electricity, natural gas,

[11] Emission allocations for the Government include emissions associated with Federal, state and local emissions. Note (1) emissions from government-owned utilities are not allocated (as discussed in Section III), (2) emissions associated with government-owned schools and educational facilities are allocated to the Education Services sector; (3) truck operations of the U.S. Postal Service are allocated to the Truck Transportation sector; and (4) emissions associated with AMTRAK and government-owned subway and bus systems are allocated to the Mass Transit Services sector.

fuel oil, propane, etc.—for heat and power, as well as the consumption of gasoline and diesel fuel for light-duty vehicles (LDVs, primarily automobiles and light-duty trucks).

Table 5. Household CO_2 Emissions: 1998, 2002, 2006, and Estimated for 2007 through 2010

Year	Total Household Emissions	Household Emissions from LDV's*	Household Emissions from Heat & Power	Number of Households	CO_2 per Household
	(Mmt)	(Mmt)	(Mmt)	(Millions)	(Mmt)
	Actual Emissions				
1998	1,631	522	1,109	102.5	16
2002	1,871	636	1,235	109.3	17
2006	1,842	608	1,234	111.6	17
	Estimated Emissions Based on EIA Forecast				
2007	1,901	615	1,286	112.5	17
2008	1,880	595	1,285	113.3	17
2009	1,869	586	1,283	114.0	16
2010	1,887	599	1,288	115.3	16

*LDV's are light-duty vehicles.
Source: ESA calculations based on EIA data for 1998, 2002, and 2006, and ESA calculations based on EIA forecasts for 2007 though 2010.

The top half of Table 5 shows total Household emissions and breaks this out into Household emissions from light-duty vehicles, and from heat and power. The last column shows emissions per household over time. The average emissions per household were about 17 metric tons of CO_2 per year. Over the period analyzed, this segment of the economy demonstrated no appreciable emissions efficiency improvements. While emissions per household are very low (and this has remained unchanged between 1998 and 2006), there are a large number of households – 111.6 million in 2006 according to the Census Bureau (U.S. Bureau of the Census, 2010 (b)). The cumulative effect makes the Household sector a significant factor in total emissions.

As Table 5 shows, for 1998, 2002 and 2006, on average, approximately one-third of all Household emissions resulted from fuel consumption in LDVs. The remaining two-thirds of the emissions were from utility use for heat and power. Between 1998 and 2006, emissions levels grew from both of these sources, as the total number of households grew. Emissions intensity followed somewhat different patterns, however. Emissions intensity from Household use of LDVs increased by a total of about 7 percent, while the emissions intensity related to Household use of utilities in residential structures increased by 2 percent.

The Household picture in 2010, however, is expected to have improved since 2006. The bottom half of Table 5 uses EIA estimates, from their Annual Energy Outlook for 2010 (U.S. Energy Information Administration, 2010(h) and 2010(i)), for Household utility use and LDV consumption of fuels through 2010. These data suggest that the trend of deteriorating emissions efficiency, both in the use of LDVs and utilities, has turned around

between 2006 and 2010. By 2010, the emissions intensity of Households is expected to be back to its 1998 level (about 16 metric tons of CO_2 per household per year).[12]

One of the reasons why emission intensities of Households may have increased over the 1998 to 2006 period is that household size has increased in each of those years as well. In 1998, there were 2.59 persons per household; by 2002, 2.63 and by 2006, 2.67. (U.S. Bureau of the Census, (c) and (d)) Using a per capita intensity ratio, this results in emissions of 6.2 Mmt of CO_2 per person in 1998, up to 6.5 Mmt in 2002 and back down to 6.2 mmt in 2006. The increase in household size through 2010, up to an estimated 2.69 persons, would lead to a 6.1 Mmt emissions per capita in that year.

E. CONCLUSION

The results in this section demonstrate the pattern of CO_2 emissions and CO_2 intensities in broad economic sectors. A number of economic sectors, Manufacturing and Other Services in particular, have experienced impressive gains in their CO_2 emissions efficiency. Manufacturing has experienced an emissions efficiency savings of 1.7 percent per year between 1998 and 2006, and has reduced its total emissions while experiencing output growth. Even so, Manufacturing is the second largest emitter of CO_2, after the Household sector.

The Household sector, which accounted for almost a third of total emissions in the U.S. in 2006, has seen no significant gains in emissions efficiency during the past decade. Even though emissions per household are low, the cumulative effect of the U.S. Household sector's consumption of energy is large.

While the pattern of overall gains in emissions efficiency in many sectors of the economy is promising, it is important to realize CO_2 emissions in the United States continue to increase (Figure 1). Furthermore, the pattern of efficiency gains is quite variable within industry sectors. Many industries within the U.S. economy have not shown consistent improvements in emissions efficiency.

V. ESTIMATING THE TOTAL CARBON FOOTPRINT OF INDUSTRIES: COMBINING DIRECT AND INDIRECT EMISSIONS (INCLUDING INDIRECT EMISSIONS PRODUCED ABROAD)

For any given industry, the direct CO_2 emissions that result from its production activities are only part of the story. In this section, we estimate the "total carbon footprint" of a sector as the sum of the direct emissions discussed in the previous section plus the indirect CO_2 emissions associated with production. Indirect emissions are those emissions that are

[12] Estimates of emissions in 2010 for industry sectors and the Government were not made since the estimates from the Outlook (U.S. Energy Information Administration, 2010(h) and 2010(i)) used to extrapolate Household estimates to 2010 are not as reliable as the source data for 1998, 2002 and 2006.

imbedded in the products that the sector purchases as inputs. For example, the CO_2 footprint of manufacturing automobiles includes not only the emissions associated with energy use in that industry, but also the CO_2 emissions embodied in the steel, glass, and plastic products used in the manufacture of motor vehicles. Moreover, because many inputs are imported from trading partners, indirect emissions do not only occur domestically, but some are produced abroad.

Estimating total emissions requirements are important for at least two reasons. First, they can help identify sectors that are relatively carbon intense in their inputs, even though they may appear relatively carbon efficient in direct emissions. Second, understanding total emissions can help quantify the change in industry costs that might be attributable to a carbon pricing scheme in the economy. For each industry, the total emissions coefficient is the elasticity (or sensitivity) of costs in that industry with respect to the price of supply chain carbon emissions, assuming that cost increases are passed along in each stage of production.[13]

A. DATA AND METHODS

We assessed interdependencies among sectors of the economy using an input-output (I-O) economic matrix, which depicts the interrelationships in an economy among industries, consumers, government, and foreign suppliers. More specifically, it shows the purchases of goods and services of each sector from the other sectors of the economy. The benchmark I-O accounts, produced by the Bureau of Economic Analysis (BEA) every five years to correspond to the Economic Census, show the detailed interindustry transactions at the level of approximately 500 sectors. It also shows the sales from each sector to final demand (consumption, investment, government, exports) and the amount of imports for each sector. The I-O table thus shows how dependent each industry is on all others in the economy, both as a consumer of their outputs and as a supplier of their inputs.

The database of Inforum's Iliad model extends BEA's five-year benchmark I-O table, using data from BEA's annual I-O tables which are available at a 65 sector level, and BEA industry accounts which provide annual data for gross output, gross output prices, and value added. The final result is time series input-output tables from 1998 through 2007, in both real and nominal terms, for 349 input-output industry sectors and the Government sector. It is this data framework that allows the estimation of total, direct, and indirect emissions across 349 industries for 1998, 2002 and 2006 using the algebra of input-output. Indirect emissions associated with imported inputs to domestic production are also calculated. The results and methodologies are described in the online appendix (which is available at http://www.esa.doc.gov/CO2/Appendix/).

Some caveats should be noted here. First of all, the generation of detailed annual input-output data for non-benchmark years – especially in real terms across time -- is an approximate process. Such estimates could have a larger degree of error relative to the five-year data published by BEA. Second, the indirect imported emissions calculation

[13] Cost increases may not be passed on at each stage of production if (1) a technology response (input substitution) in the production process offsets the full cost increases of inputs and/or (2) inputs from other sources can be had at reduced prices, such as from imports.

assumes that the CO_2 emissions intensity of each sector is the same abroad as it is domestically. This could be a heroic assumption for many industries. For these reasons, we caution that the estimates of indirect emissions should be viewed as more approximate than the estimates of direct emissions discussed in the previous section.

This report serves as a summary of the more detailed estimates, and Tables 5 and 6 provide some information on direct and indirect emissions for broad industry sectors. In these tables, total and indirect emissions cannot be added across sectors. This is because a direct emission from one industry often becomes an indirect emission for another industry that buys its products. For example, in Table 6, the indirect emissions of Fabricated Metal Products contain the direct emissions of the Primary Metals that are used for production of Fabricated Metal Products. Therefore, adding Primary Metals to Fabricated Metals would result in double counting total emissions.

While we provide estimates of indirect emissions in this report for broad economic sectors, the true value of such estimates lies at the detailed industry level, where they may be used to simulate the impact of changes in climate change policy. For instance, these estimates could be used to calculate the impact of a climate policy on costs of production (cost of production may be driven by the price pass-through of indirect inputs).[14]

With these notes in mind, the remaining parts of this section discuss indirect emissions at the aggregate level for all economic sectors of the economy (Table 5), and for Manufacturing (Table 6). At the end of this section, we focus on two specific industries, very important to the consumption spending of Households—Autos and Health Care.

B. DIRECT AND INDIRECT EMISSIONS

Direct, indirect, and total emissions by aggregate economic sectors are shown in Table 6. The table also breaks down indirect emissions into its domestic and imported components. The total carbon footprint of each of these aggregate economic sectors is an estimate of its total emissions, that is, direct plus indirect emissions.

[14]Input-output relationships in a forecast of a carbon pricing scheme may be problematic, i.e., they may change with the introduction of markedly higher prices because the I-O framework does not account for behavioral response and substitution patterns. As a result, the estimated effects to industries predicted by the I-O model can be seen as a ceiling.

Table 6. Direct, Indirect and Total Emissions, 2006 Aggregate Economic Sectors

Aggregate Economic Sector (NAICS)	Emissions (Mmt CO_2)				Share of Total Emissions in Sector		
		Indirect				Indirect	
	Direct	Domestic	Imported	Total	Direct	Domestic	Imported
Agriculture (11)	42.8	34.3	9.5	86.6	49.4%	39.6%	10.9%
Mining (21)	183.4	17.2	4.3	204.9	89.5%	8.4%	2.1%
Utilities (22)*	0.0	62.7	22.5	85.1	0.0%	73.6%	26.4%
Construction (23)	156.6	179.8	58.5	394.9	39.7%	45.5%	14.8%
Manufacturing (31-33)	1,516.2	433.7	121.2	2,071.1	73.2%	20.9%	5.9%
Retail and Wholesale Trade (42, 44, 45)	328.8	141.3	20.7	490.9	67.0%	28.8%	4.2%
Transportation and Warehousing (48-49)	912.1	51.6	16.4	980.1	93.1%	5.3%	1.7%
Other Services (51-81)	786.1	473.9	121.8	1,381.8	56.9%	34.3%	8.8%
Government (92)	288.9	19.5	6.5	314.8	91.8%	6.2%	2.1%
Households[15]	1,841.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total U.S. Economy	6,056.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

*Direct emissions associated with Utilities are passed on to end users in other sectors.
n.a. indicates that indirect emissions are not additive.
Source: ESA calculations based on data on Appendix Tables A-61, A-62 and A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

Table 6 shows that direct emissions from Manufacturing came to 1,516 Mmt and indirect emissions (emissions in other sectors of the economy as well as from imports) added another 555 Mmt, resulting in a total of 2,071 Mmt of CO_2 emissions in 2006 from Manufacturing production. Of the 555 Mmt associated with indirect emissions, 434 Mmt were from domestic production and 121 Mmt were emitted abroad. Thus for the Manufacturing sector, direct emissions accounted for the majority (73 percent) of total emissions; domestically produced indirect emissions accounted for 21 percent, and indirect emissions resulting from imports accounted for 6 percent of total emissions.

In contrast, the Construction industry had a large share of indirect emissions. In 2006, the direct emissions of the Construction industry were 157 Mmt, only 40 percent of its total carbon footprint. Domestic indirect emissions (180 Mmt) and imported indirect emissions (59 Mmt) accounted for 46 percent and 15 percent, respectively, of its total carbon footprint. Direct emissions were a large share of total emissions in Mining, Transportation, and Government. In Agriculture and Construction, less than half of total emissions came from direct production.

B.1 Manufacturing: Direct and Indirect Emissions

The Manufacturing sector plays a significant role in CO_2 emissions, even though it has made improvements in emissions efficiency, as shown in Table 2. Table 6 shows that direct emissions accounted for the majority (73 percent) of total emissions in

[15] The carbon footprint of the household sector cannot be computed directly since this sector is not included in the input-output matrix.

Manufacturing. Table 7 shows direct, indirect, and total emissions by 3-digit NAICS sectors within Manufacturing. The results in Table 7 on the detailed Manufacturing sectors show that direct and indirect emissions, as share of total emissions, vary considerably within Manufacturing.

Table 7. Manufacturing: Direct, Indirect and Total Emissions, 2006

Industry Title (NAICS)	Emissions (Mmt CO_2)				Share of Total Emissions		
		Indirect				Indirect	
	Direct	Domestic	Imported	Total	Direct	Domestic	Import
Total Manufacturing	1,516.2	433.7	121.2	2,071.1	73.2%	20.9%	5.9%
Food (311)	101.7	96.7	19.6	218.0	46.6%	44.4%	9.0%
Beverage and Tobacco Products (312)	10.2	25.1	5.3	40.6	25.1%	61.9%	13.0%
Textile Mills (313)	22.5	6.4	2.3	31.2	72.1%	20.6%	7.3%
Textile Mill Products (314)	4.1	9.7	3.6	17.4	23.6%	55.7%	20.7%
Apparel (315)	2.4	5.1	1.7	9.2	26.2%	55.8%	18.0%
Leather and Allied Products (316)	0.4	1.0	0.2	1.6	25.3%	60.1%	14.6%
Wood Products (321)	25.2	16.9	3.6	45.7	55.2%	37.1%	7.8%
Paper (322)	89.7	21.9	5.7	117.3	76.5%	18.7%	4.8%
Printing and Related Support (323)	13.1	18.0	4.5	35.5	36.9%	50.6%	12.5%
Petroleum and Coal Products (324)	323.7	123.9	87.5	535.1	60.5%	23.2%	16.3%
Chemicals (325)	307.3	92.6	24.6	424.5	72.4%	21.8%	5.8%
Plastic and Rubber Products (326)	48.5	46.7	17.2	112.4	43.1%	41.5%	15.3%
Nonmetallic Mineral Products (327)	160.3	21.1	6.3	187.6	85.4%	11.2%	3.3%
Primary Metals (331)	193.9	26.1	7.4	227.4	85.3%	11.5%	3.3%
Fabricated Metal Products (332)	48.0	57.4	17.8	123.1	39.0%	46.6%	14.4%
Machinery (333)	34.0	59.9	19.5	113.4	30.0%	52.8%	17.2%
Computer and Electronic Products (334)	32.4	37.8	9.6	79.7	40.6%	47.4%	12.0%
Electrical Equip., Appliances, and Components (335)	14.4	20.4	6.3	41.1	35.0%	49.6%	15.3%
Transportation Equipment (336)	66.0	115.2	36.6	217.7	30.3%	52.9%	16.8%
Furniture and Related Products (337)	8.8	15.3	4.2	28.3	31.1%	53.9%	15.0%
Miscellaneous Manufacturing (339)	9.6	21.3	6.3	37.2	25.8%	57.2%	17.0%

Source: ESA calculation based on Appendix Tables A-61, A-62 and A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

It is important to note that the aggregate data on indirect emissions for Manufacturing capture only the amount that occurs outside the Manufacturing sector.[16] In other words, because of the double-counting issue, there can be no intra-sector indirect emissions in the aggregate Manufacturing total. The data for more detailed Manufacturing sectors, on the contrary, capture the indirect requirements from Manufacturing sectors outside their own. For instance, the Transportation Equipment sector's indirect requirements can come from other industries within Manufacturing, like Primary Metals (steel), Plastics, Electronic Equipment, and from industries in the Service sector.

The sectors that retain a high direct emissions share, at the 3-digit NAICS level, include Textile Mills (72 percent), Wood Products (55 percent), Paper (77 percent), the Petroleum

[16] Care needs to be taken to interpret the results associated with indirect inputs to production. For example, while the direct emission share of the aggregate sector Primary metals is 85 percent, one of its component industries, Primary aluminum, has a direct emissions share of 53 percent. See Appendix Table A-63 (available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls).

industry (61 percent), Chemicals (72 percent), Non-metallic Mineral Products (85 percent), and Primary Metals (85 percent). These sectors are often called "basic industries" because they do not require as many indirect inputs from outside of their own sector. Also, the inputs they purchase have a relatively low emissions level, except the Petroleum industry. The emissions from products produced by the Petroleum industry are accounted for when the product is used, such as in LDVs. However, it should be noted that the direct emissions of Petroleum, Chemicals, Non-metallic Mineral Products, and Primary Metals are relatively high.

The sectors that retain a high indirect emissions share include Beverages and Tobacco (75 percent, which is the sum of 62 percent in domestic indirect and 13 percent in imported indirect), Textile Mill Products (76 percent), Apparel (74 percent), Leather (75 percent), Machinery (70 percent), Transportation Equipment (70 percent), Furniture (69 percent), and Miscellaneous Manufacturing (74 percent). The final output of these sectors, such as autos or aircraft for the Transportation Equipment sector, requires a great deal of fabrication and the indirect inputs to production are many. The share of imported emissions in these high indirect emissions sectors varies from 13 percent in Beverage and Tobacco products to 21 percent in Textile Mill Products. This implies that imported emissions in these high indirect emissions sectors account for almost a fifth (17 percent in Beverages and Tobacco) to slightly more than a fourth (27 percent in Textile Mill Products) of total indirect emissions.[17]

B.2 Households

While we cannot calculate a total carbon footprint for Households in a way consistent with our calculations for industries, we can provide some examples of how such an indicator may be produced using available data. Personal consumption expenditures (PCE) by Households in 2006 were over $9 trillion and can be broken down into expenditures for goods, both durable and non-durable—about one-third of PCE—and services—the remaining two-thirds. The following are examples of the emissions resulting from personal consumption of a good—Motor Vehicles—and of a service—Health Care.

PCE for Motor Vehicles and Parts make up about one-third of all consumer durable goods spending. We estimate in this study that the Motor Vehicle and Light Truck industry has a fairly low direct emissions profile—for each $1 billion of output in 2006, 0.047 Mmt of CO_2 is emitted from Motor Vehicle production. But we also estimate that to support this $1 billion of Motor Vehicle production, another 0.568 Mmt of CO_2 will be emitted in the production of goods and services within other industries that are used in Motor Vehicles. Thus, total emissions of 0.615 Mmt of CO_2 are associated with the production of each $1 billion of output from the domestic Motor Vehicle industry, much larger than their direct emissions suggest.

In 2006 the output of the Motor Vehicle industry was valued at approximately $240 billion (2000 dollars). This means that the direct emissions from the Motor Vehicle industry were

[17] As mentioned earlier in Section V.A, Data and Methods, summing across emissions associated with indirect inputs across industries would result in double-counting and should not be done.

only about 11 Mmt, while another 136 Mmt of CO_2 was emitted from industries that produced goods and services needed for Auto production. Of these indirect emissions, about 76 Mmt was from domestic production of indirect products and about 60 Mmt was produced outside the U.S. This suggests that the total carbon footprint of consumer spending on Motor Vehicles was 147 Mmt of CO_2.

In 2006, PCE for Health Care was about $1.4 trillion, approximately 24 percent of consumer spending on services. The Health Care sector—from physicians to hospitals to child care services—has a low emissions profile. About 0.074 Mmt of CO_2 is emitted for each $1 billion of output in Health Care in 2006. In addition to its direct emissions, the emissions from indirect requirements are another 0.167 Mmt, resulting in a total direct and indirect emissions intensity estimate of 0.240 Mmt per $1 billion of Health Care sector output. This means that the total emissions intensity profile of the Health Care sector is relatively low, compared to the 0.615 Mmt of direct and indirect emissions from the above example for Autos.

However, since the revenue (output measure) associated with Health Care is very large, total emissions of CO_2 associated with this industry was 303 Mmt—90 Mmt directly and 213 Mmt indirectly. This 303 Mmt of direct and indirect emissions for Health Care in 2006 is much larger than the 147 Mmt of total CO_2 emissions resulting from consumer purchase of automobiles in the above example.

C. CONCLUSION

The discussion and results in this section should be interpreted with care and provide only an illustrative example of the full magnitude of emissions that may be generated by any one sector. Some industries have a total carbon footprint that is much larger than their direct emissions. For instance, the Construction industry generates a high share of its emissions indirectly through the purchase of products from other sectors of the economy. On the other hand, the Transportation Services industry has a relatively small amount of indirect emissions.

There is a great deal of variation across and within economic sectors on the share of emissions that are generated directly versus indirectly. Even within Manufacturing, which generates the majority of its emissions through direct production, there are a number of detailed industries that have a high degree of emissions associated with indirect inputs.

VI. CARBON EMISSIONS AND TRADE

Using the analyses presented in this report so far, it is possible to estimate CO_2 emissions associated with total U.S. domestic production, as well as total imports and total exports of goods and services. Table 8 provides estimates of emissions associated with domestic production, imports, exports, and total U.S. consumption or domestic demand. The estimated imports emissions in Table 8 include emissions from imported final goods, such as autos, as well as imported indirect inputs for U.S. domestic production, such as auto parts used in domestic auto production.[18] The emissions associated with aggregate domestic demand (shown in the final column of Table 8) are measured by the emissions related to domestic production plus the emissions related to imports minus the emissions related to exports. Note that at the beginning of Section V, we mentioned a number of caveats which make these emissions estimates approximate (see Section V.A).

Table 8. CO_2 Emissions From: Domestic Production, International Trade, and Demand

	Emissions (in Mmt) from:			
	Domestic Production (a)	Imports (b)	Exports (c)	Domestic Demand (a+b-c)
1998	5,728.7	370.3	272.0	5,827.0
2006	6,056.7	437.2	291.6	6,202.3

Source: ESA calculations using CO_2 intensities (Appendix Tables A-61 and A-63, available online at http://www.esa.doc.gov/CO2/Appendix/tables/tablesA60-A63.xls), and data on Import Shares of Consumption and Export Shares of Production from Inforum's Iliad Model.

According to Table 8, emissions associated with total imports in 2006 were 437.2 Mmt or about 7.0 percent of emissions associated with total domestic demand (6,202.3 Mmt), up just slightly from 6.4 percent in 1998. This suggests that, according to our approximate estimates, emissions associated with total imports are a small fraction of total U.S. emissions.[19] Emissions associated with exports in 2006 were 291.6 Mmt, or about 4.7 percent of emissions related to domestic demand, and largely unchanged from 1998.

In 2006, total imports accounted for 16.7 percent of GDP, and exports comprised 11.0 percent of GDP. Comparing the emissions shares calculated from Table 8 and the GDP shares suggests that the shares of imports and exports emissions were smaller than the GDP shares of imports and exports. While total imported emissions accounted for 7.0 percent of

[18] In the previous discussion of emissions due to imports used for indirect input purchases, we cautioned about adding emissions across sectors due to the possibility of double-counting inputs to production. In Table 8, we have eliminated the possibility of double-counting by adding emissions due to imports from all sources, whether as an imported input to U.S. domestic production or an imported final good. The sum of these pieces equals the total. Emissions associated with domestic production, imports, and exports in Table 8 were calculated based on direct emissions coefficients.

[19] Even if we assume that foreign production is 50 percent more polluting, across all industries, than domestic production, the emissions associated with U.S. consumption that come from imports would still be only about 10 percent.

U.S. consumption in 2006, note that imports of Petroleum alone amounted to 13.5 percent of the total value of imports. However, the emissions from U.S. products, which use imported Petroleum as an input, are only counted as emissions from the end users, such as gasoline in autos.

VII. CONCLUSION

This report has presented an assortment of findings related to emission intensities and efficiencies. Chief among them are the following:

- Between 1997 and 2007, the U.S. economy became more emissions efficient. Carbon intensity declined at the same time as GDP increased. While CO_2 emissions increased over this time period, they would have risen 25 percent more without the declines in carbon intensity.

- Private industry is the largest direct emitter of CO_2 in the nation, emitting over twice as much CO_2 as Households and several more times than Government. Private industry has shown much greater gains in emissions efficiency, however, than have the Household and Government sectors between 1998 and 2006.

- The Manufacturing sector -- the focus of much of the discussion about pollution control -- was responsible for about one-quarter of total CO_2 emissions in 2006 and has made significant gains in emissions efficiency over the 1998 to 2006 period.

- The Household sector generated almost a third of total U.S. emissions in 2006 and has not seen any appreciable efficiency gains over the last decade.

- Looking only at direct emissions does not give a full picture of the emissions attributable to an industry. As a result, we look at both direct and indirect emissions in the last part of this report. These results on indirect emissions are particularly useful at the more detailed industry level, since they can be used to investigate how changes in energy policies that affect one industry sector may impact other sectors.

    - Comparing carbon footprints across industries can help to determine the full impact of these industries on CO_2 emissions. Looking only at direct emissions can provide a misleading picture of the impact of an industry on energy usage. For example, while the Food and Construction industries have relatively low levels of direct emissions intensity, the inputs that each of these industries require for production result in a relatively large CO_2 emissions footprint. The footprint could be reduced substantially by these industries converting to lower emission-intense inputs.

There are other published measures of CO_2 emissions by industry available, particularly for the Manufacturing sector. This study differs in that it is focused on CO_2 emissions in detailed industry sectors and is applied in a comprehensive scope across the U.S. economy at several points in time. For this reason, these estimates of emissions intensity and their change over time provide a richer and more comprehensive picture of the ultimate sources

of manmade CO_2 emissions. In addition, the estimates of "total carbon footprint" by industry sectors, including the effects on CO_2 emissions abroad, further adds to our understanding of the ways in which the U.S. economy generates CO_2 emissions.

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Attachment – Industries Assessed in Study Using the Inforum Iliad Model

1	Oilseed farming
2	Grain farming
3	Vegetable and melon farming
4	Fruit and nut farming
5	Greenhouse, nursery, and floriculture production
6	Tobacco farming
7	Cotton farming
8	Sugarcane and sugar beet farming
9	All other crop farming
10	Cattle ranching and dairy farming
11	Poultry and egg production
12	Animal production, except cattle and poultry and eggs
13	Forestry and logging
14	Fishing, hunting and trapping
15	Agriculture and forestry support activities
16	Crude oil extraction
17	Natural gas extraction
18	Coal mining
19	Iron ore mining
20	Copper, nickel, lead, and zinc mining
21	Gold, silver, and other metal ore mining
22	Stone mining and quarrying
23	Sand, gravel, clay and refractory mining
24	Other nonmetallic mineral mining
25	Oil and gas drilling and support activities
26	Support activities for other mining
27	Electric Utilities
28	Natural gas distribution
29	Water, sewage and other systems
30	New residential construction
31	New non-residential building construction
32	Highway, street, bridge, and tunnel construction
33	Water, sewer, and pipeline construction
34	Other new construction
35	Maintenance and repair of residential structures
36	Maintenance and repair of nonresidential buildings
37	Maintenance and repair of infrastructure, and other nonresidential maintenance and repair
38	Dog and cat food
39	Other animal food
40	Flour and rice milling, and malt
41	Wet corn milling
42	Soybean and other oilseed processing
43	Fats and oils refining and blending
44	Breakfast cereals
45	Sugar manufacturing
46	Confectioneries
47	Frozen food
48	Fruit and vegetable canning and drying
49	Dairy products
50	Meat products, except poultry
51	Poultry processing
52	Seafood product preparation and packaging
53	Bakery and pasta products
54	Other food manufacturing, snacks, coffee, condiments, nuts, etc.
55	Soft drink and ice manufacturing
56	Breweries
57	Wineries
58	Distilleries
59	Tobacco products
60	Fiber, yarn, and thread mills

61	Fabric mills
62	Textile and fabric finishing mills
63	Carpet and rug mills
64	Curtain and linen mills
65	Other textile and fabric product mills
66	Hosiery
67	Knit apparel, except hosiery
68	Apparel, cut and sewn
69	Accessories and other apparel
70	Shoes and other leather products
71	Sawmills and wood preservation
72	Veneer, plywood, particleboard, and engineered wood products
73	Millwork
74	Wood containers and pallets
75	Manufactured homes, mobile homes
76	Prefabricated wood buildings
77	Miscellaneous wood products
78	Pulp mills
79	Paper and paperboard mills
80	Paperboard containers
81	Flexible packaging foil and surface coated paperboard
82	Paper bag and coated and treated paper
83	Stationery products
84	Sanitary paper products
85	All other converted paper products
86	Printing
87	Support activities for printing
88	Petroleum refineries
89	Asphalt products
90	Lubricating and other petroleum products
91	Petrochemicals
92	Industrial gas
93	Synthetic dyes and pigments
94	Other basic inorganic chemicals
95	Other basic organic chemicals
96	Plastics material and resins
97	Synthetic rubber
98	Cellulosic organic fibers
99	Noncellulosic organic fibers
100	Fertilizers
101	Pesticide and other agricultural chemicals
102	Pharmaceuticals and medicines
103	Paints and coatings
104	Adhesives
105	Soaps and cleaners
106	Toiletries
107	Printing ink
108	Explosives
109	Custom compounding of purchased resins
110	Photographic films and chemicals
111	Other miscellaneous chemical products
112	Plastics packaging materials, film, and sheet
113	Plastics pipe, fittings, and profile shapes
114	Laminated plastics plate, sheet, and shapes
115	Plastic foam products
116	Plastic bottles
117	Resilient floor coverings
118	All other plastics products
119	Tires
120	Rubber and plastics hose and belting

121	Other rubber products
122	Pottery, ceramics, and plumbing fixtures
123	Clay building materials and refractories manufacturin
124	Glass containers
125	Glass and glass products, except containers
126	Cement
127	Ready-mix concrete
128	Concrete products
129	Lime
130	Gypsum products
131	Abrasive products
132	Cut stone and stone products
133	Other nonmetallic mineral products
134	Primary ferrous metal products
135	Primary aluminum production
136	Aluminum products
137	Primary copper
138	Nonferrous metal products, exept copper and aluminum
139	Copper products
140	Nonferrous metal processing except copper and aluminum
141	Ferrous metal foundaries
142	Aluminum foundries
143	Nonferrous foundries, except aluminum
144	Iron and steel forging
145	Nonferrous forging
146	Custom roll and stampings
147	All other forging and stamping
148	Cutlery and flatware
149	Hand and edge tools, saws and sawblades
150	Kitchen utensils, pots and pans
151	Architectural and structural metal products
152	Power boilers and heat exchangers
153	Metal tank (heavy gauge) manufacturing
154	Metal cans, boxes, and other containers
155	Hardware, spring, and wire products
156	Machine shops, screws, nuts, bolts, turned products
157	Metal coating, engraving, heat treating, and allied activities
158	Metal valves
159	Ball and roller bearings
160	Small arms
161	Other ordnance and accessories
162	Other miscellaneous fabricated metal products
163	Ammunition
164	Farm, lawn and garden machinery and equipment
165	Construction machinery
166	Mining, oil and gas field machinery and equipment
167	Sawmill and woodworking machinery
168	Plastics and rubber industry machinery
169	Paper industry machinery
170	Textile machinery
171	Printing machinery and equipment
172	Food product machinery
173	Semiconductor machinery
174	All other industrial machinery
175	Office machinery
176	Optical instruments and lenses
177	Photographic and photocopying equipment
178	Other commercial and service industry machinery
179	Automatic vending, commercial laundry and drycleaning machinery
180	Air purification and ventilation equipment

181	Heating equipment, except warm air furnaces
182	AC, refrigeration, and forced air heating
183	Industrial mold manufacturing
184	Metal cutting and forming machine tool
185	Special tools, dies, jigs, fixtures, cutting tools, machine tool accessories
186	Rolling mill and other metalworking machinery
187	Turbine and turbine generator set units
188	Other engine equipment manufacturing
189	Speed changers and mechanical power transmission equipment
190	Pump and compressor manufacturing
191	Elevators and moving stairways
192	Conveyor and conveying equipment
193	Industrial cranes, hoists, trucks and trailers
194	Power-driven handtools
195	Welding and soldering equipment
196	Packaging machinery
197	Industrial process furnaces and ovens
198	Fluid power equipment
199	Scales, balances, and miscellaneous general purpose machinery
200	Electronic computers
201	Computer storage devices
202	Computer terminals
203	Other computer peripheral equipment
204	Telephone apparatus
205	Broadcast and wireless communications equipment
206	Other communications equipment
207	Audio and video equipment
208	Semiconductors and electron tubes
209	All other electronic components
210	Electromedical apparatus
211	Search, detection, and navigation instruments
212	Measuring devices and controls
213	Electricity and signal testing instruments
214	Analytical laboratory instruments
215	Irradiation apparatus
216	Watches, clocks, and other measuring and controlling devices
217	Software, audio, and video media reproduction
218	Magnetic and optical recording media manufacturing
219	Electric lamp bulb and part manufacturing
220	Lighting fixtures
221	Electric housewares, fans and vacuum cleaners
222	Household cooking appliances
223	Household refrigerators and home freezers
224	Household laundry equipment
225	Other major household appliances
226	Electric power and specialty transformers
227	Motors and generators
228	Switchgear and switchboard apparatus
229	Relays and industrial controls
230	Storage batteries
231	Primary batteries
232	Fiber optic and other cable
233	Wiring devices
234	Carbon and graphite and miscellaneous electrical equipment
235	Automobiles and light trucks
236	Heavy duty trucks
237	Motor vehicle bodies
238	Truck trailers
239	Motor homes, travel trailers and campers
240	Motor vehicle parts

241	Aircraft
242	Aircraft engines and engine parts
243	Other aircraft parts and equipment
244	Guided missiles and space vehicles
245	Propulsion units and parts for space vehicles and guided missiles
246	Railroad rolling stock
247	Ship building and repairing
248	Boat building
249	Motorcycle, bicycle, and parts
250	Military armored vehicles and tank parts
251	All other transportation equipment
252	Wood kitchen cabinets and countertops
253	Household and institutional furniture
254	Office furniture (including fixtures)
255	Mattresses, blinds and shades
256	Laboratory apparatus and furniture
257	Surgical and medical instruments
258	Surgical appliance and supplies
259	Dental equipment and supplies
260	Ophthalmic goods
261	Dental laboratories
262	Jewelry and silverware
263	Toys and sporting goods
264	Office supplies, except paper
265	Sign manufacturing
266	Gasket, packing, and sealing devices
267	Musical instruments
268	Other miscellaneous manufacturing
269	Wholesale trade
270	Retail trade
271	Air transportation
272	Rail transportation
273	Water transportation
274	Truck transportation
275	Transit and ground passenger transportation (includes S&L government)
276	Pipeline transportation
277	Support activities for transportation and sightseeing
278	Couriers and messengers
279	Warehousing and storage
280	Newpaper publishers
281	Periodical publishers
282	Book publishers
283	Database, directory, and other publishers
284	Software publishers
285	Motion picture and video industries
286	Sound recording industries
287	Radio and television broadcasting
288	Cable networks and program distribution
289	Telecommunications
290	Information services
291	Data processing services
292	Banks, savings institutions, and credit unions
293	Credit cards and finance companies
294	Securities, commodity contracts, investments
295	Insurance
296	Funds, trusts, and other financial vehicles
297	Real estate
298	Owner-occupied dwellings
299	Automotive equipment rental and leasing
300	Video tape and disc rental

301	Machinery and equipment rental and leasing
302	Rental of other goods
303	Lessors of nonfinancial intangible assets (royalties)
304	Legal services
305	Accounting and bookkeeping
306	Architectural and engineering services
307	Specialized design services
308	Custom computer programming
309	Computer systems design services
310	Other computer related services, including facilities management
311	Management consulting
312	Environmental and other technical consulting services
313	Scientific research and development
314	Advertising and related services
315	Photographic services
316	Veterinary services
317	All other miscellaneous professional and technical services
318	Management of companies and enterprises
319	Office administrative services
320	Facilities support services
321	Employment services
322	Business support services
323	Travel arrangement and reservation services
324	Investigation and security services
325	Services to buildings and dwellings
326	Other support services
327	Waste management and remediation services
328	Elementary and secondary schools
329	Colleges, universities, and junior colleges
330	Other educational services
331	Home health care services
332	Offices of physicians, dentists, and other health practioners
333	Other ambulatory health care services
334	Hospitals
335	Nursing and residential care facilities
336	Child day care services
337	Social assistance, except child day care services
338	Performing arts, spectator sports, museums & related activities
339	Amusements, gambling, & recreation activities
340	Hotels and other accommodation
341	Food services & drinking places
342	Automotive repair, maintenance and car washes
343	Electronic equipment repair & maintenance
344	Commercial machinery repair & maintenance
345	Household goods repair & maintenance
346	Personal care services
347	Death care services
348	Drycleaning & laundry services
349	Other personal services
350	Government