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# The Role of US Households in Global Carbon Emissions

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## 1. Introduction

United States (US) is currently responsible for about 20% of global carbon emissions. The residential sector is responsible for a little over 20% of this emission. From this perspective, US households account for about 4% of global carbon emissions. Such sector-based approach is commonly used in energy analysis and energy policy. However, this is not necessarily a complete representation of the reality of household carbon emissions. The residential sector includes all energy directly used by homes and related carbon emissions. Two important elements are missing in this approach: energy used for transportation by people living in these homes and the embodied energy in all non-energy goods and services consumed by them. Another approach for reporting household emissions, based on the various end uses of energy in US homes, provides a more detailed understanding of the use of energy for heating, cooling, cooking, appliances, consumer electronics and automobiles. This approach also falls short of identifying emissions beyond the residential sector and personal transportation sub-sector. There is, however, another way of estimating total household carbon emissions. The industrial sector produces products that are transported by the transportation sector and marketed by the commercial sector and eventually consumed by people. Therefore, people in the US consume energy directly in the form of electricity, natural gas, and other fuels for their homes and automobiles. They also consume energy indirectly through the consumptions of various products and services. Combining the emissions related to the direct and indirect consumption of energy, people are accountable for about 71% of US carbon emissions (Shammin & Bullard, 2009) – which is significantly higher than the 20% represented by the residential sector. According to this approach, US households account for about 14% of global carbon dioxide ($CO_2$) emissions – roughly equal to the total emissions of the 27 member states of the European Union. People in the US thus have a significant opportunity to contribute to the reduction of global carbon emission[1].

This chapter presents a new, more comprehensive, more interesting and above all, more empowering approach to household carbon emissions in the US. It focuses on how US households contribute to greenhouse gas emissions, how they can play an important role in

[1] In this chapter *carbon emissions* and *$CO_2$ emissions* are used interchangeably. All data are reported for $CO_2$.

reducing global carbon emissions, and also how such efforts will potentially make them more resilient in the long run.

## 2. Carbon emissions by US households

There are multiple ways of estimating household carbon emissions. In fact, currently there is no established system of calculating and reporting total household carbon emissions for US households that includes a comprehensive accounting of the various ways households are directly and indirectly responsible for carbon emissions. US Environmental Protection Agency (EPA) and Energy Information Agency (EIA) both publish yearly reports on US greenhouse gas (GHG) emissions. These reports are organized around the major sectors of the economy (henceforth referred to as the *Sectoral* approach) and provide a macro-level overview of US GHG emissions. Another way household GHG emissions are often reported is based on various energy end uses – such as appliances, HVAC (heating, ventilation and air conditioning) systems, lights, cars, etc. (henceforth referred to as the *End Use* Approach). The sections below investigate the current methods of estimating carbon emissions under both of these approaches. Some boundary conditions need to be established prior to that. About 83% of US GHG emissions are carbon based of which more than 98% is energy-related (see figure 1). Hence the specific analysis of this paper will focus mainly on energy related carbon emissions. It should, however, be noted that GHG emissions from non-carbon sources also play a significant role in global climate change particularly on a global scale, but they are kept outside of the scope of this analysis.

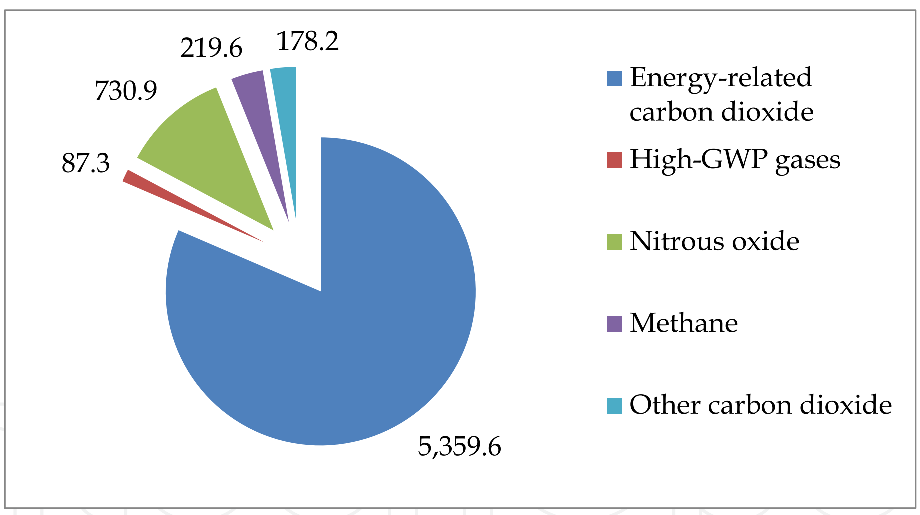


Fig. 1. 2009 US greenhouse gas emissions by gas in million metric tons (EIA, 2011)

### 2.1 The sectoral approach

The *sectoral* approach looks at the four major sectors of the US economy: residential, commercial, industrial and transportation. Emissions from electricity generation are distributed between these sectors, but are also sometimes reported separately. This picture is technically sound and the accounting method is time-tested - resulting in fairly accurate estimation of total carbon emissions for the economy as a whole by adding up the parts (see figure 2). This approach is consistent with government planning, budgeting and other fiscal activities. The *sectoral* approach also helps in the development of appropriate policies for managing carbon emissions for the different sectors. Still, the *sectoral* approach provides a limited understanding of the total carbon emissions and ways of reducing emissions at the household level. It implies that households are responsible for primarily residential emissions and part of the transportation related emissions. Perhaps this is because the *sectoral* approach is not organized around people, their behavior, and their lives; rather it is categorized on the basis of macro-economic activities. Hence, the *sectoral* analysis is limited in its ability to explicitly represent the different ways people interact with the various economic sectors.

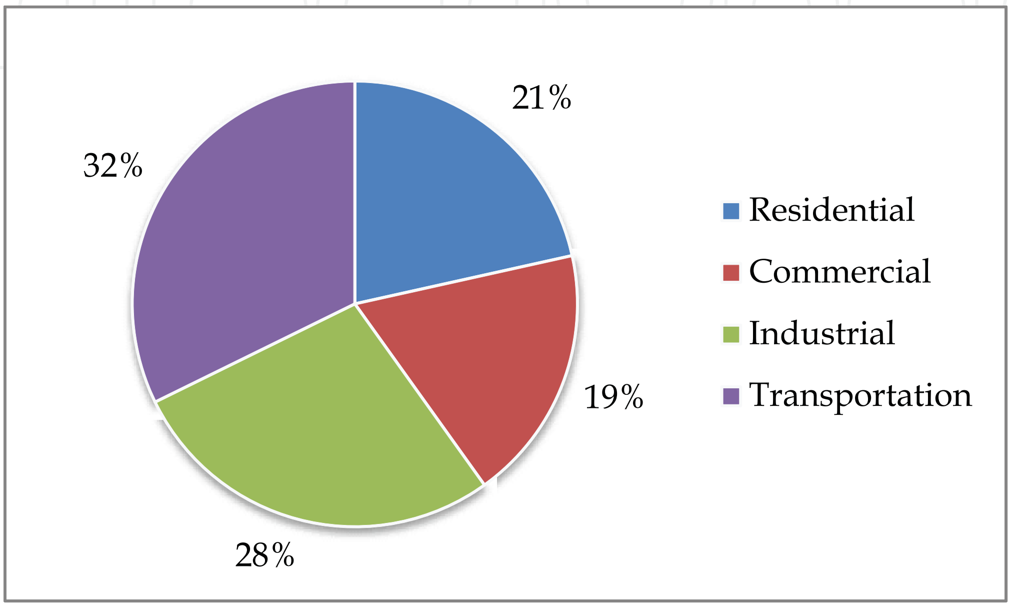


Fig. 2. US $CO_2$ emissions by economic sectors (EIA, 2011)

It is possible to link people's lives with the economic sectors included in *sectoral* analysis. First, the residential sector emissions are directly attributable to individuals in US households. These are emissions resulting from electricity, natural gas (or propane), fuel oil, wood, and other fuels used as a source of energy by residential consumers. People have a reasonable level of control over their use of these resources – within the constraints of existing infrastructure and resource availability. Second, a large part of emissions from the transportation sector are from personal automobiles. This part of the transportation sector emission is also directly attributable to people. Similar to the first case, people have a lot of control over their transportation emissions: choice of transportation mode, fuel efficiency of automobiles, place of residence relative to workplace and other daily destinations, etc. Together, the two above cases account for about 39% of carbon emissions that can be linked directly to people (based on data for 2009 from EIA, 2011). The remaining 61% is more complicated and requires deeper understanding of the life cycle of products and services. As mentioned earlier, the industrial sector produces products that are transported by the transportation sector and marketed by the commercial sector and eventually consumed by people. Sometimes there are multiple layers in the supply chain of products. Some industrial outputs are transported as parts or input materials for other industries before eventually making it to the marketplace. People are not always direct consumers either. Industries themselves consume various products or services and so do various commercial enterprises and non-governmental organizations. Another big consumer is the government itself – for its various organizations including defense (military, air force, navy and various intelligence agencies). Ultimately all these different consumptive activities and related carbon emissions can be linked back to people. They are all intended to provide people with essential and non-essential products (including public infrastructure) and services (including social services and national security). These linkages are not clearly identifiable in the current representation of the *sectoral* analysis of carbon emissions.

### 2.2 The end use approach

In contrast to the *sectoral* approach, the *end use* approach provides a more detailed overview of micro-level energy use and carbon emissions by US households. Under this approach, the various energy end uses in households are documented and related carbon emissions are quantified. This includes energy used by HVAC systems, cooking, water heating, appliances, lighting, and other devices such as televisions, computers, and other household electronics. EIA routinely conducts the Residential Energy Consumption Survey (RECS) to generate data for *end use* analysis. The results of the *end use* approach is important for understanding the relative magnitudes of energy consumption by different systems within households and identifying opportunities for conservation and efficiency improvements to reduce household GHG emissions. While this approach is crucial for the purposes stated above, it is still limited to direct consumption of energy and related emissions. It provides a more in-depth understanding of residential sector emissions, but does not shed any additional light on the linkages between households and the other economic sectors listed under the *sectoral* approach.

### 2.3 Towards a more complete accounting of household emissions

Over the past four decades development of input-out analysis using methods developed by Nobel Laureate Wassily Leontief (Leontief, 1970) has made it possible to use economic input-out analysis to carry out more complete estimates of household energy consumption and carbon emissions. This is based on two related concepts: a) life cycle analysis: a method of estimating the impact of any resources use over its life cycle - from the point of raw material extraction to ultimate disposal of postconsumer wastes; and b) embodied energy (or embodied carbon): energy use or carbon emissions that occur at various stages over the life cycle of products and services that people eventually consume. This is applicable to both direct energy resources (electricity, natural gas, gasoline and other fuel) and non-energy goods and services (food, clothing, entertainment, insurance etc.). The following two examples illustrate this. A life cycle perspective of gasoline demonstrates that it is not just the emissions resulting from burning gasoline in automobiles, but energy is used and carbon emissions occur for finding, drilling, transporting, refining, and marketing gasoline. These add about 25% carbon emissions that are indirectly attributable to gasoline use. Therefore, the embodied $CO_2$ emissions for gasoline is 2.3 kg/liter from direct burning and an additional 0.6 kg/liter from indirect sources – resulting in a total embodied $CO_2$ of 2.9 kg/liter. While this example explains life cycle analysis and embodied emissions for an energy resource, all non-energy goods and services also have similar embodied life cycle emissions. For example, energy related emissions take place throughout the life cycle of the clothes people buy. If all these emissions are added up and normalized for every dollar spent on clothing in the US, the embodied $CO_2$ emissions for clothing amount to 0.43 kg/$.

Life cycle analysis – particularly for all products and services in an economy - appears to be a daunting task. This is where Leontief's work on input-output analysis came in handy. Originally developed for macro-economic analysis, Leontief formulated a mathematical process of inverting the complex matrix of all inter-sector transactions in an economy to derive the total final consumption of individual sectors (Leontief, 1970). This allowed for tracking the flow of money through and between sectors in any given year. Robert Herendeen, Bruce Hannon, Clark Bullard, and others associated with the Energy Resources Group at the University of Illinois carried out the seminal work of using Leontief's method to track the flow of money spent on energy resources (or in some cases the physical flows of energy) within the US economy and then converting the results into the physical quantities of energy used by various industries and enterprises. When this data is combined with national consumer expenditure data, one can actually estimate both the energy intensities of products and services and of households of different income groups (Bullard & Herendeen, 1975; Herendeen & Tanaka, 1976; Herendeen, 1978; Herendeen et al., 1981). Notable follow-up work that builds on this approach has been done by Manfred Lenzen of University of Sydney, Rutger Hoekstra of Statistics Nederlands, and many others who used this approach to not only estimate energy intensities but also carbon emissions and other environmental impacts. Hoekstra (2010) compiled a database of the development of environmental analysis based on Leontief's input-out method. More recent estimates of energy and carbon intensities are reported in Shammin et al (2010), Shammin & Bullard (2009), and Bin & Dowlatabadi (2005). These papers primarily used the Economic Input Output Life Cycle Analysis (EIOLCA) database developed at Carnegie Melon University[2]. This method now allows for a much more complete and in-depth understanding of household energy use and carbon emissions that can directly be linked to people's behavior and choices. While details on the methods can be found in the papers cited above, figure 3 provides a generic outline of the process of using economic input-output analysis to estimate carbon intensities for goods and services and combining that with consumer expenditure data to derive total household carbon emissions.

## 3. Consumption based household $CO_2$ emissions

An analysis of the US economy on the basis of personal consumption and other expenditures presents a very different perspective than the *sectoral* and *end use* approaches. In this view, based on data from the Bureau of Economic Analysis, personal consumption expenditures in 2003 accounted for about 70% of the gross domestic product (GDP) while the remaining 30% was shared by government expenditure, investment, and net exports[3]. Here, US households contributed about 4.17 billion metric tons of $CO_2$ emissions through their consumption of various goods and services – about 71% of the national total emissions of 5.86 billion metric tons[4]. Based on numbers reported in figure 4, a few key indicators can be calculated for 2003: the energy and $CO_2$ intensities of the economy were 10,058 kJ/$ and

[2] Carnegie Mellon University Green Design Institute. Economic Input-Output Life Cycle Assessment (EIO-LCA), Available from: http://www.eiolca.net

[3] For consumption based household emissions, all numbers are for the year 2003 for consistency with the results of economic input-output analysis of embodied energy and carbon reported in Shammin et al (2010) and Shammin & Bullard (2009).

[4] These calculations are based on data from Table 1.5 of the Annual Energy Outlook 2007 published by the EIA and results reported in Shammin & Bullard (2009).

0.55 kg/$ respectively; annual per-capita emission was 20 metric tons/person; and annual per-household emission was 51 metric tons/household.

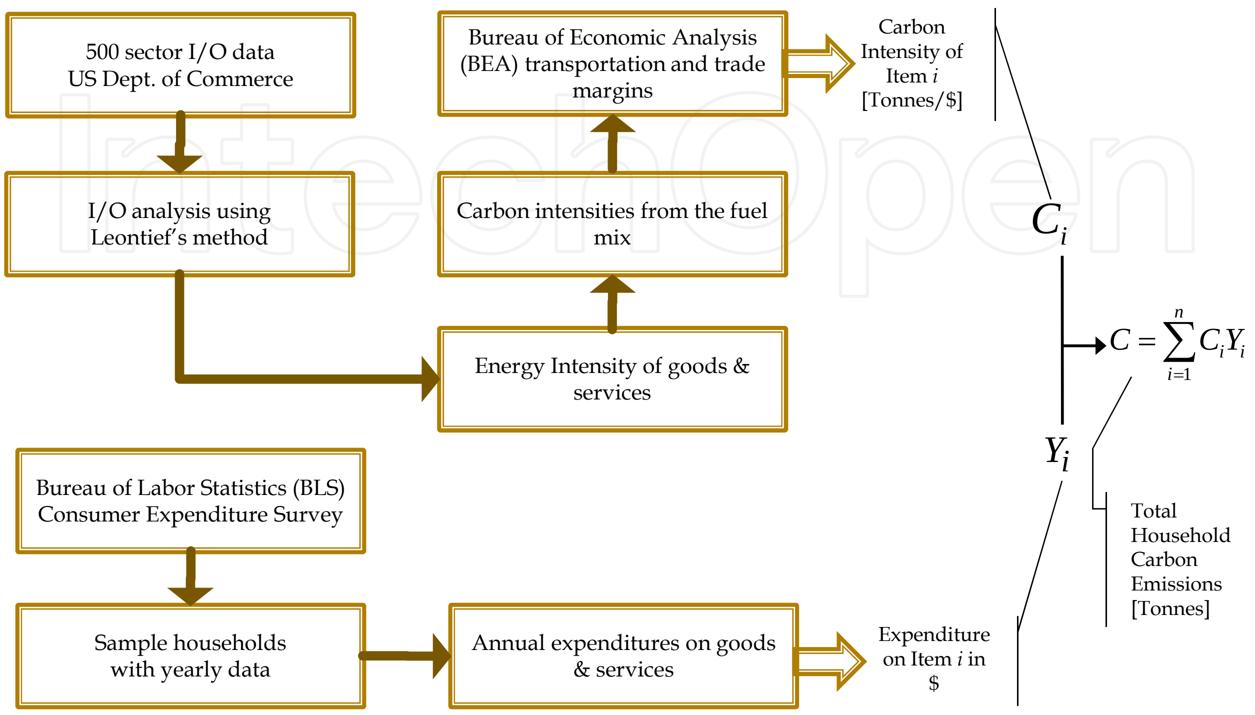


Fig. 3. Process of calculating carbon intensities using economic input-output analysis and total household carbon emissions by summing the product of carbon intensity and consumer expenditure data for individual sectors across all *n* consumer items. (Shammin, 2009)

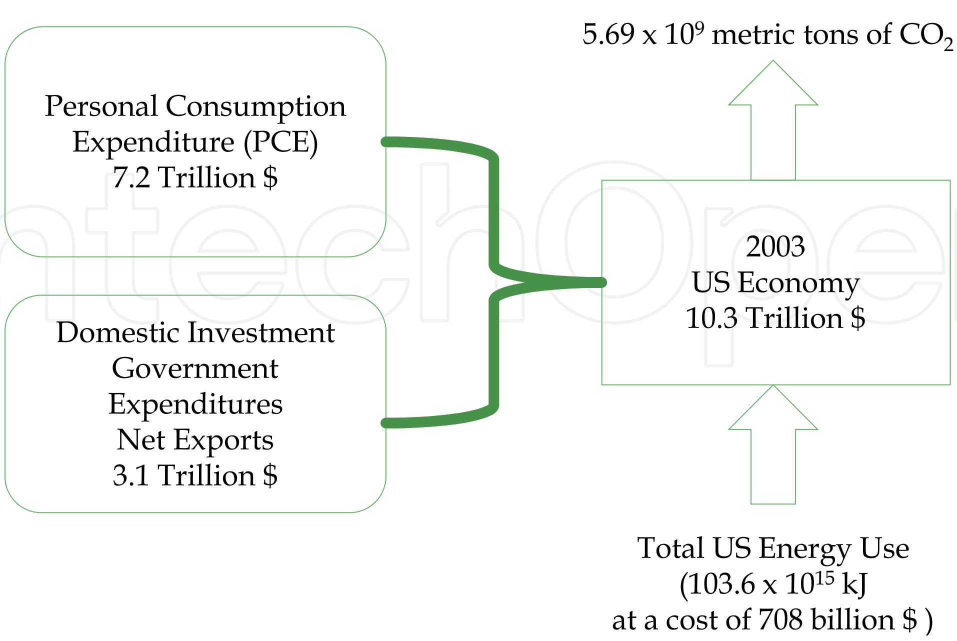


Fig. 4. GDP components, energy use and $CO_2$ emissions for the US economy, 2003. (Based on data from EIA and BEA)

The consumption based perspective on household emissions communicates a very different message to people. It shows that people have the power to directly and indirectly affect a large component of the nations' carbon emissions through behavior and lifestyle changes that would affect their consumption patterns and preferences. People also have the power to affect the remaining 29% of emissions; however, that would require engagement beyond personal choices. Through political activism and voting patterns, people in a democracy have the power to communicate how the government should spend their tax dollars. Regarding domestic investment, increasingly there are options being available to make investment choices on the basis of environmental performance. Finally, export-import policies can be reformed to trade with partners that are more environmentally responsible. None of this is easy; but at least this way of relating people and their behavior with national carbon emissions and mitigation opportunities provides a perspective that is either missing or inadequately addressed in the *sectoral* and *end use* approaches.

### 3.1 $CO_2$ emissions by the average US household

The most recent results to date for consumption-based carbon emissions for US households are reported in Shammin & Bullard (2009). The methods are based on calculations of energy intensities using input-output analysis described in Shammin et al (2010). These two papers also discuss the assumptions, nuances, and uncertainties associated with this approach. In 2003, the average household in the US spent about $49,000 of which only 6.5% was spent on direct energy. The total embodied $CO_2$ emission per household was about 37 metric tons of which about 65% was from direct energy. Thus, a small percent of household expenditure is actually responsible for the bulk of its carbon emissions. However, it is also interesting to see that the remainder of household expenditures made on non-energy goods and services were responsible for about 35% of the total embodied carbon emissions by the average household. This is a significant part of household emissions that is associated with life cycle emissions and the linkages between people and the sectors of the economy beyond residential and personal automobiles. The breakdown of total expenditure and total embodied carbon emissions are shown in figure 5a and 5b.

### 3.2 $CO_2$ Intensities of consumption categories

Shammin & Bullard (2009) reports detailed carbon intensities for all personal consumption categories based on standard classification of the Bureau of Labor Statistics. A list of carbon intensities for major consumption categories is given in table 1. The distribution of carbon emissions between expenditure categories shown in figure 5b and the intensities in table 1 together provide valuable insights into household energy consumption and related conservation opportunities.

It is important to understand the different implications of the magnitude of $CO_2$ emissions attributable to households (~37 metric tons/household-yr), the percentage share of specific consumption categories (~38% for residential energy), and the above carbon intensities. The total annual carbon emission, which is the grand total derived by summing the products of the carbon intensities and expenditures for individual items as shown earlier in figure 3, is actually the ultimate measure for the carbon footprint of a given household. Energy efficiency and conservation measures are intended to reduce this total emission. It is now a common consensus among most proposals for climate legislation that US needs to reduce

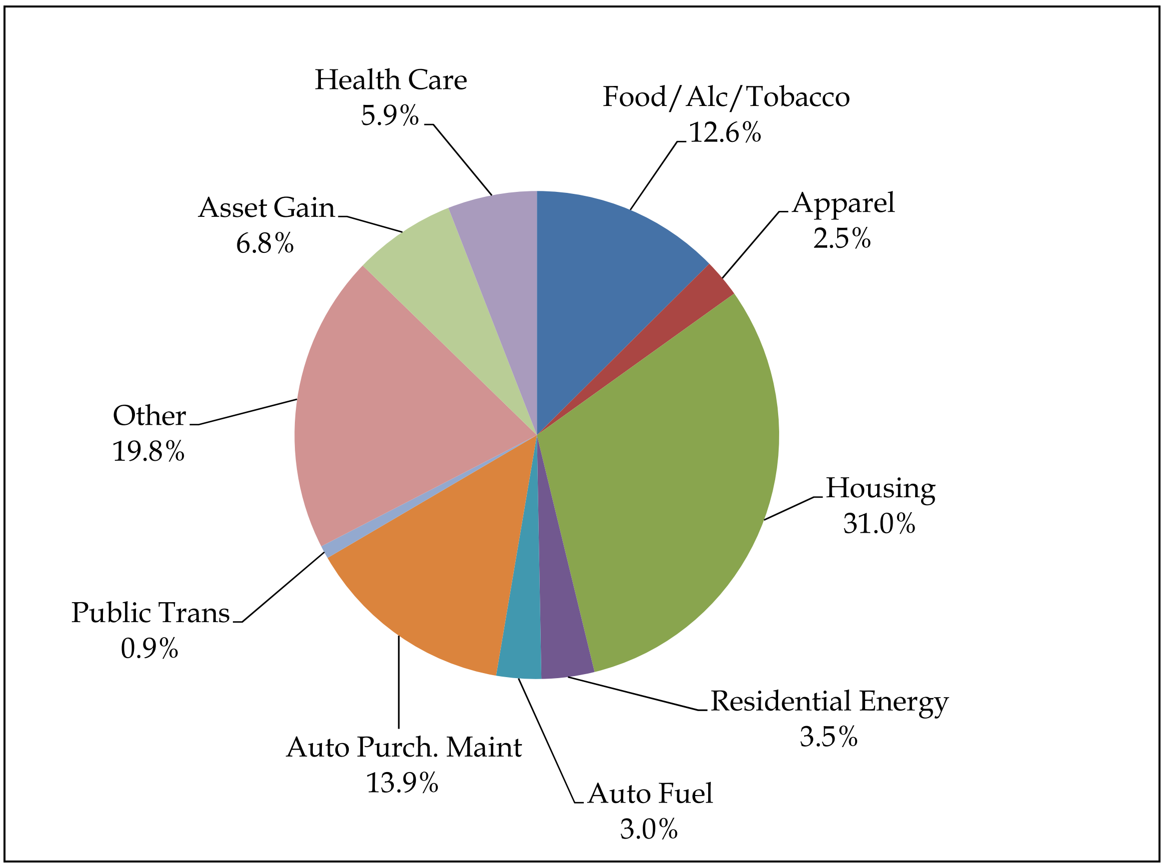


Fig. 5a. Breakdown of annual expenditures for the average US household in 2003

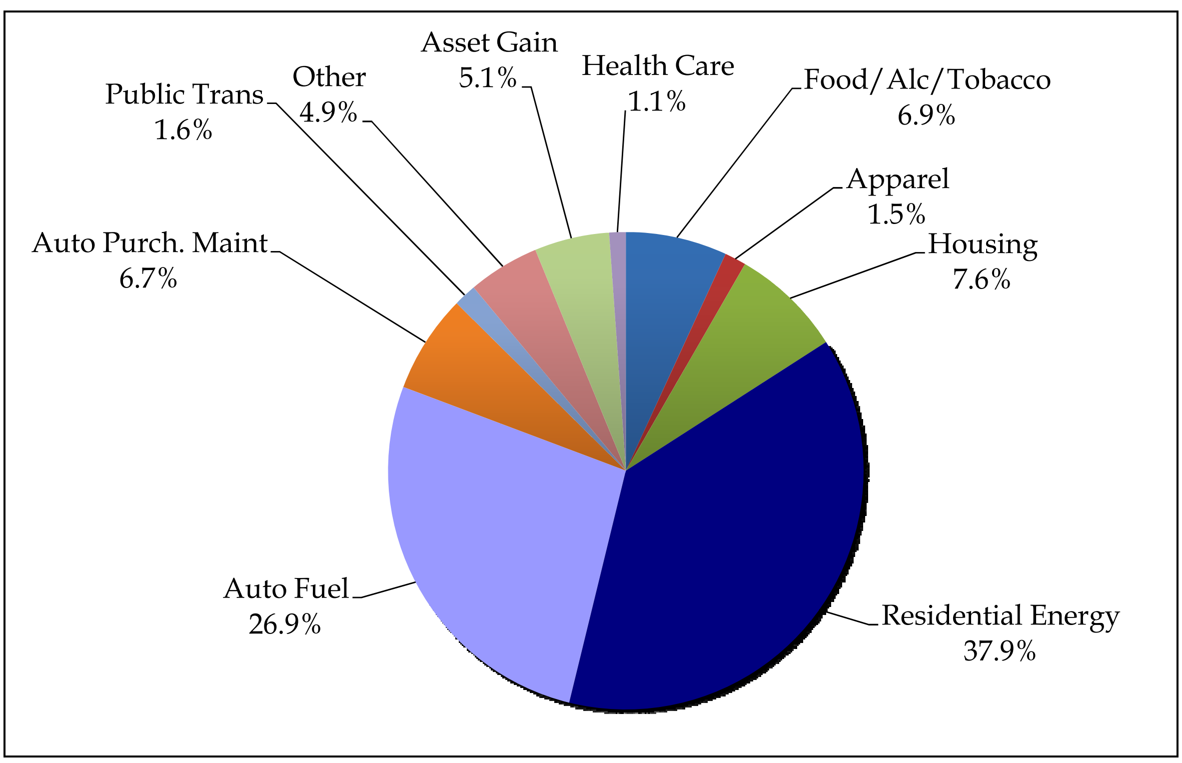


Fig. 5b. Breakdown of annual $CO_2$ emissions for the average US household in 2003

$CO_2$ emissions by 80% or more. This cannot be achieved without significant reductions at the household level. Share of emissions by specific consumption categories is also important because small percent reductions in large categories can result in a bigger difference than large percent reductions in small categories. Finally, carbon intensities indicate how carbon efficient different consumption categories are and provide an explicit basis for comparisons across categories.

| | **$CO_2$ Intensity (kg/$)** |
|---|---|
| Average $CO_2$ Intensity (all categories) | 0.80 |
| Average $CO_2$ Intensity of Direct Energy | 7.53 |
| Natural gas | 6.25 |
| Electricity | 8.02 |
| Fuel oil and other fuels | 8.07 |
| Gasoline and motor oil | 6.87 |
| Average $CO_2$ Intensity of Indirect Energy | 0.32 |
| Housing | 0.34 |
| Owned dwellings | 0.24 |
| Telephone services | 0.17 |
| Water and other public services | 0.59 |
| Household operations | 0.16 |
| Housekeeping supplies | 0.34 |
| Household furnishings and equipment | 0.33 |
| Housing structure | 0.80 |
| Cars and trucks, new | 0.46 |
| Cars and trucks, used | 0.50 |
| Other vehicles | 0.66 |
| Vehicle finance charges | 0.14 |
| Maintenance and repairs | 0.29 |
| Vehicle insurance | 0.07 |
| Vehicle rental, leases, licenses, other charges | 0.19 |
| Public transportation | 1.38 |
| Food | 0.41 |
| Alcoholic beverages | 0.33 |
| Tobacco products and smoking supplies | 0.13 |
| Apparel, footwear and related services | 0.43 |
| Health care | 0.14 |
| Personal care products and services | 0.27 |
| Entertainment | 0.22 |
| Reading/education | 0.21 |
| Cash contributions | 0.27 |
| Personal insurance and pensions | 0.11 |
| Miscellaneous | 0.28 |

Table 1. $CO_2$ intensities of major household consumption categories.

### 3.3 Predictors of household $CO_2$ emissions

Energy consumption and related carbon emissions vary across households depending on several key demographic and lifestyle related factors. Household income is the most influential predictor of total household emissions and how those emissions are distributed across various consumption categories. In general, the relationship between income and carbon emissions is non-linear (figure 6) – resulting in regressive impacts on low income households (Shammin & Bullard, 2009).

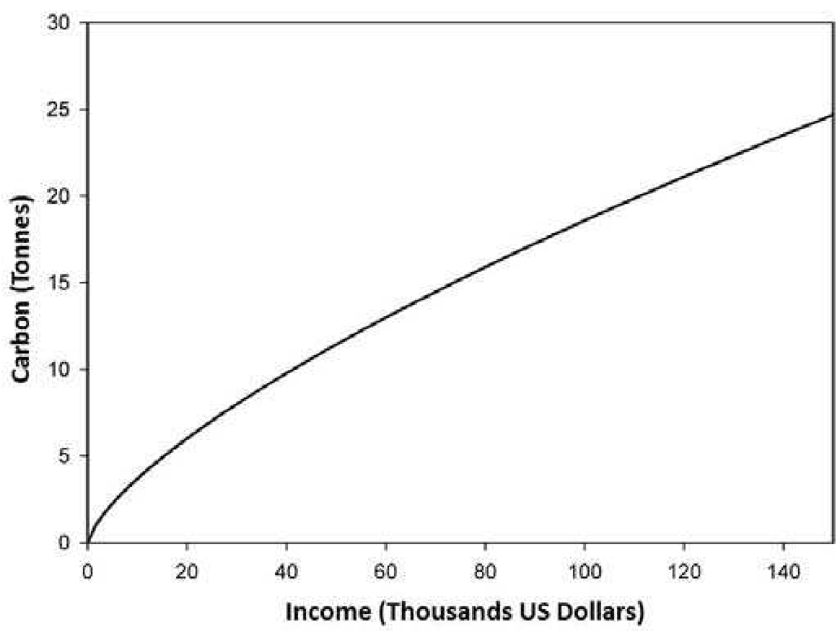


Fig. 6. Relationship between annual household income and carbon emissions. (Shammin & Bullard, 2009)

There is a large difference in the total annual carbon emissions and the share of indirect carbon emissions between households belonging to the lowest and highest income quintiles. In 2003, the total $CO_2$ emission of the highest quintile (~68 metric tons) was four times higher than that of the lowest quintile (~17 metric tons). At the same time, the share of indirect emission was close to 50% for the highest quintile as opposed to less than 20% for the lowest quintile. The latter has important implications: if price of direct energy resources go up as a result of climate change legislations, the effect on low income households will be disproportionately higher than high income households. Figure 6 shows that if a new cap-and-trade or carbon tax policy puts a price on carbon emissions at $100/metric ton, the impact on low income households can be more than 4% of their income as opposed to less than 2% for high income households (Shammin & Bullard, 2009).

Another important predictor of household emissions is the location of residence. Households in rural areas consumed about 17% higher total energy compared to households of the same income level residing in urban locations. Bigger homes, longer commutes, greater use of outdoor power equipment, etc. are typically responsible for this difference. Other predictors that affect total household energy consumption include: family size (about 28% more for a family of 4 compared to single-occupant households), number of cars (about 27% more for a household with two cars compared to households with no cars), and housing type (about 44% more for single-family homes compared to apartments). These differences, reported in Shammin et al (2010), are estimated for households with the same income having different demographic and lifestyle configurations. While these differences are for total energy consumption, they would yield very similar differences in total household carbon emissions as well.

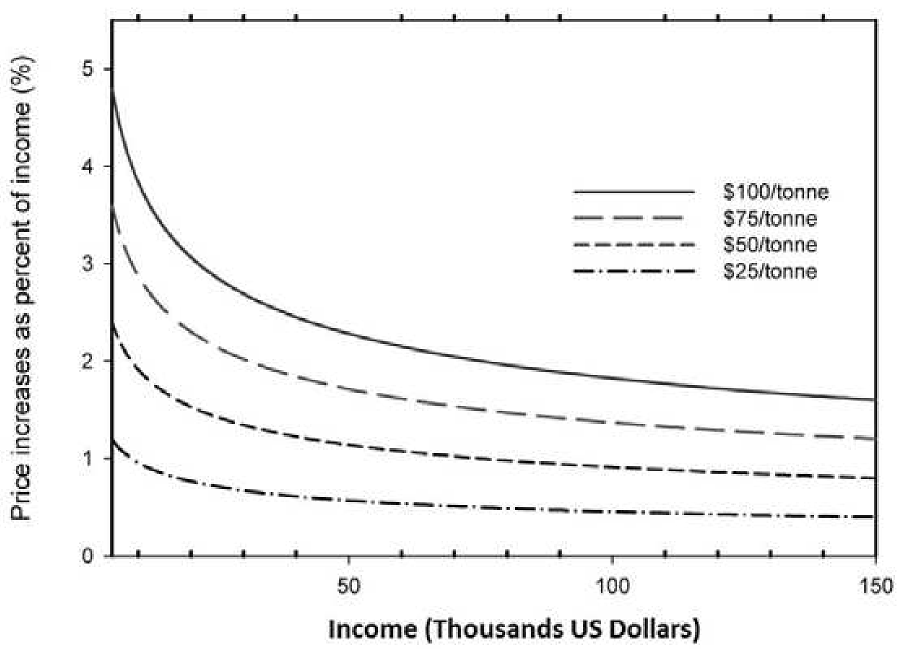


Fig. 7. Price increases for goods and services consumed by households as percent of annual household income due to different prices of carbon emissions. Here, emission data is for carbon and not $CO_2$ and tonne = metric tons. (Shammin & Bullard, 2009)

## 4. The role of households in reducing $CO_2$ emissions

Consumption based approach to household carbon emissions puts households and the people living in them front and center in exploring ways of reducing national carbon emissions. This requires households to develop a comprehensive strategy for carbon emission reductions that involves specific actions to address the various sources of emissions: direct emissions, indirect emissions, and emissions related to government expenditure, investment, and net exports. A pre-requisite for this is the motivation and willingness by members of any given household to undertake the solutions that apply to them. Literature in environmental psychology has several studies that investigate ways of motivating people to change behavior and adopt conservation and efficiency measures to reduce their carbon footprint (Nolan et al, 2008; Parnell & Larsen, 2005). Examples of successful interventions from some recent research include: innovative ways of providing real time feedback on energy and resource use (Petersen et al 2007; Petersen & Frantz, 2009) and offering financial incentives for reducing resource consumption (Suter & Shammin, 2010). Once households are committed to reduce emissions, they have to balance several different approaches to address their total emissions. Throughout this process, households need to monitor their carbon footprint and track their progress in order to achieve most effective results. People are used to budget their income and expenses on a regular basis. Current challenges of climate change require people to go beyond financial budgeting and begin to develop methods to monitor their energy use and carbon emissions. The paradigm shift and associated challenges required for this to become mainstream involve discussions that are beyond the scope of this chapter.

The *end use* approach mentioned earlier provides the basis for reductions of direct emissions for households within the scope of the residential sector and personal transportation sub-sector. These mostly include direct conservation and efficiency measures that households can take.

*Conservation measures:* these involve reducing carbon intensive behaviors or replacing carbon intensive behaviors with emission-free options. Examples include:

a. walking/biking instead of using automobiles
b. reducing number of daily trips using motorized transportation
c. using clotheslines instead of dryers
d. making weather appropriate clothing choices indoors and airflow/shade management instead of using air conditioning
e. lowering thermostat setting in winter and raising it in summer
f. lowering water heater temperature
g. choosing to live in a smaller home
h. choosing to drive a smaller automobile

*Efficiency measures:* these involve replacing less efficient equipment with more efficient ones to achieve the same task. Examples include:

a. upgrading inefficient HVAC systems and appliances
b. improving insulation and reducing leakage in homes
c. using more efficient water heaters
d. replacing incandescent light bulbs with compact fluorescent or light emitting diode light bulbs
e. taking inventory of household electronics, eliminate unnecessary ones, and using power strips and on/off switches to avoid phantom loads
f. using public transportation instead of personal automobile
g. replacing fuel-inefficient vehicles with more fuel-efficient vehicles
h. regular maintenance of home appliances, HVAC equipment, and automobiles
i. installing renewable energy systems in homes such as solar, wind, geothermal, etc.
j. building homes that are designed to maximize the use of passive solar energy

The interplay between conservation and efficiency measures is also important to understand. Here, the ultimate goal is to reduce carbon emissions. However, overemphasis on efficiency measures may lead to *Jevon's Paradox* (people replacing inefficient cars with efficient ones and then driving more miles than before to offset or overshoot energy/carbon savings). On the contrary, when conservation and efficiency measures are coupled, households will be able to maximize their emission reductions. Dietz et al (2009) shows that reasonably achievable household emissions reduction in the US can be approximately 20% within 10 years if the most effective non-regulatory interventions are used.

In addition to the direct emissions, consumption based approach also allows for households to understand, estimate, monitor and reduce indirect carbon emissions. US society has been on a treadmill of consumption for several decades where more consumption is considered a desirable goal. The core message in this approach is that consumption of non-energy goods and services has associated life cycle carbon emissions and thus reducing consumption would help reduce carbon emissions. As shown in table 1, there is very little difference in the carbon intensity of the various consumption categories responsible for indirect carbon emissions. Any reduction in consumption, irrespective of which items are avoided, would yield similar reductions in a household's carbon footprint. Notable exceptions are water and public transportation. Another related issue is rebound effects. If money saved from the reduction of direct energy is re-spent on other goods and services, part of the conservation savings would be offset. For example, if a household saves $1,500 by conserving direct energy consumption, they would reduce their $CO_2$ emissions by about 11 metric tons. If that money is re-spent on other goods and services, that would generate about 0.5 metric tons of additional $CO_2$ – resulting in a net savings of 10.5 metric tons. For a single household this may appear to be a small effect, but added across the economy this addition amounts to more than 50 million metric tons. This effect can become much larger if this money is re-spent on more carbon intensive choices such as flying to far-away places for family vacations.

Influencing the components of GDP beyond personal consumption (see figure 4) requires a different approach – since these involve decision making entities that are exogenous to individual households. A democratic society has avenues for people to influence decisions made by the government about how public tax dollars should be spent – through voting patterns, writing letters to representatives, and other types of civic engagement and political activism. If government expenditure on building roads is shifted towards the development of high speed rail or government subsidy to fossil fuels is shifted towards new incentives for renewable energy projects, significant reductions in carbon emissions can be achieved in the government expenditure component. It is also important to note that reductions of direct and indirect carbon emissions by households would not change the carbon intensity of the underlying infrastructure such as the source mix of power generation or transportation driven by internal combustion engines. Reduction in household electricity use would only go so far if more than 80% of the electricity is generated from coal (which is the case in many US states such as Ohio). Through activism and engagement, people have the opportunity to influence a shift from carbon intensive fossil fuel based sources to carbon-neutral or carbon-free renewable sources. This will have a large impact on economy-wide reductions in carbon emissions.

In terms of the investment component of GDP, many investment portfolios now make information on environmental performance or carbon offsets available to investors. If more and more people invest in these green stocks, the carbon footprint of investment can go down. Perhaps the most complicated component of GDP for people to influence is net exports – as this involves carbon emissions associated with industries and commercial ventures in other countries. Reforms in trade policies can allow more partnerships with countries, industries and multi-national companies that promote climate friendly operations. If policy is ultimately reflective of the will of the people, then households can play a role in paving the way for such transitions from carbon intensive to a low carbon or carbon-free economy.

Finally, reducing carbon emissions is not necessarily about compromises and sacrifices. There are multiple benefits of low carbon lifestyle in a low carbon economy for households. First, humanity is currently threatened by the grim prospect of catastrophic consequences unless human-induced climate change is slowed, halted or reversed. While there are theories about winners and losers in a post climate change world, in reality everyone is at risk as the global economy is now more interconnected than ever before. We have already seen how crisis in East Asian markets had ripple effects throughout the world and how economic downturn in the US is affecting other countries. Locally, households, communities and regions with low carbon footprint will be more resilient against increased prices of carbon intensive energy resources and consequent increases in the price of goods and services. Thus, a more comprehensive and aggressive strategy for reducing carbon emissions by households, particularly in a carbon intensive nation such as the US, makes sense on many levels: for the sustainability of human race, for a healthy environment for future generations, for economic stability, for social security, and for the development of more engaged and resilient communities.

## 5. Conclusion

The daunting task of combating climate change is a defining challenge of the present generation. Reducing global carbon emissions is the most important aspect of that challenge. The US is a major player in global climate mitigation initiatives – since it is responsible for more than 20% of global carbon emissions. While the residential sector in the US accounts for about 20% of US emissions, this chapter demonstrates that households can directly and indirectly play a very important role in reducing all of the nations' carbon emissions. They have direct control over about 46% of embodied carbon emissions in the US by managing their consumption of energy resources and indirect control over another 25% of emissions by managing their consumption patterns. They can also play a role in influencing the remaining 29% by promoting and/or supporting initiatives to reduce the carbon footprint of energy systems, government expenditures, investment portfolios, and even businesses and industries beyond US borders. They can do this by becoming more engaged citizens and exercising their democratic privileges. The *sectoral* and *end use* approaches used to represent household emissions in the US are important, but limited in terms of helping people fully understand how their lives are connected to all sectors of the economy. The consumption based approach presented in this chapter constitute a more comprehensive accounting of household emissions as it includes embodied carbon over the life cycle of products and services that people consume to support their lifestyle. Most importantly, this approach offers people much more direct ways of relating personal choices with large scale reductions of national carbon emissions. This is a perspective that has the potential to empower people to become proactive agents of change and provide more explicit tools to make a difference in the battle against climate change.

## 6. Acknowledgment

I would like to acknowledge my co-authors of the two papers (Shammin & Bullard, 2009; Shammin et al, 2010) that formulate the conceptual and analytical basis for the main arguments presented in this paper. Special thanks go to Robert A. Herendeen at the University of Vermont and Clark W. Bullard at the University of Illinois for their mentorship and collaboration on the research that has made this chapter possible.

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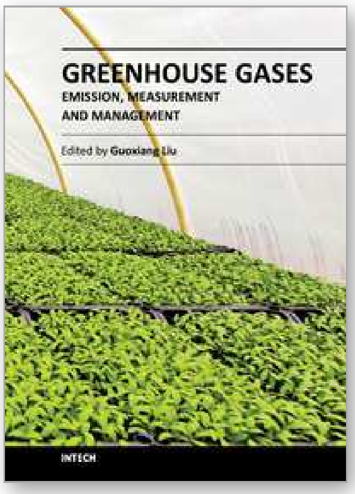

**Greenhouse Gases - Emission, Measurement and Management**

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Understanding greenhouse gas sources, emissions, measurements, and management is essential for capture, utilization, reduction, and storage of greenhouse gas, which plays a crucial role in issues such as global warming and climate change. Taking advantage of the authors' experience in greenhouse gases, this book discusses an overview of recently developed techniques, methods, and strategies: - A comprehensive source investigation of greenhouse gases that are emitted from hydrocarbon reservoirs, vehicle transportation, agricultural landscapes, farms, non-cattle confined buildings, and so on. - Recently developed detection and measurement techniques and methods such as photoacoustic spectroscopy, landfill-based carbon dioxide and methane measurement, and miniaturized mass spectrometer.



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