EVALUATION OF CARBON DIOXIDE EMISSIONS BY KANSAS AGRIBUSINESS RETAILERS

by

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B.S., Zamorano University, 2006

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2010

Approved by
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Abstract

Greenhouse gas (GHG) emissions and their negative effect on the environment is a growing concern in the world. It is estimated that agriculture is responsible for 7% of the total GHG emissions in the United States. Currently, environmental policies to regulate GHG are in place in different countries and are expected to increase in the future. Increased awareness about climate change by customers also represents an incentive for companies in measuring their emissions.

The objective of this study is to estimate carbon dioxide-equivalent emissions from eight agribusiness retailers in Kansas. Data consisted of two years of energy inputs from the operation of the agribusiness retailers. Carbon emission coefficients were employed to determine carbon dioxide-equivalent emissions associated with the use of each energy input during their operations.

Results suggest that electricity is the largest source of total carbon dioxide emissions from the retail operations followed by diesel fuel. Diesel fuel represents the main source of direct emissions and gasoline represents the second largest source of direct emissions. Emissions from the agricultural sector will not be regulated under the current American Clean Energy and Security Act of 2009 but information on their potential carbon footprint may be used in identifying specific processes where emissions could be reduced and to analyze possible climate legislation implications for their operations. If agribusinesses were to be regulated, none of the eight retailers have locations with emission levels that would be subject to the current cap and trade bill passed by the U.S. House of

Representatives. But, if they were regulated and had to comply by purchasing carbon credits equal to 5 to 20% of their direct emissions, the cost would be low given estimation of future carbon prices in the literature. Even if agricultural retailers are not directly restricted, they will likely be affected by increases in energy input prices if such legislation is enacted.

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ACKNOWLEDGMENTS

I want to begin by thanking the Agricultural Marketing Resource Center for their assistance in funding this research. I would also like to recognize the Arthur Capper Cooperative Center at Kansas State University for all they do to make studies like this possible. The contribution and backing from these eight case study cooperatives cannot be overstated.

I am also very grateful for the employees of the retail agribusiness firms who partnered with me and provided the invaluable data used in this study. I give them my special gratitude for sparing the extra time and effort to advance the cause of agricultural research and education.

I would like to express my appreciation to Zara Clayton-Niederman and Dr. Lanier Nalley at the University of Arkansas for their help in finding carbon information and for providing me with carbon coefficients from their Ecoinvent database. It was wonderful to collaborate with such outstanding professionals.

I would also like to recognize the Department of Agricultural Economics at Kansas State University for funding my studies. They have shown such faith and confidence in my abilities over the last year and a half, and I look forward to continuing my development with them as I enter the PhD program this fall.

To my major professor, Dr. Boland, I give my most grateful thanks. Throughout this process, he has been a tremendous source of support, guidance and especially the right

amount of push when I needed it. Thanks for the consideration, insights and expertise you pass on to all your students.

In addition, I would to thank my committee members, Dr. Jason Bergtold, Dr. Jeff Williams and Dr. David Barton for their ideas, advice and the time you provided me. You each bring a great amount of proficiency to my study.

Last, but definitely not of the least importance, I would to thank my many family and friends for their prayers, support and love. I could never have done this without the things each of you add to my life.

GLOSSARY

Carbon Allowance: “A carbon credit that has been distributed to the holders up to their permitted level of CO_2e emissions” (Williams *et al.*, 2009, p.32).

Carbon credit: “A permit that allows the holder to emit 1 Mt CO_2e” (Williams *et al.*, 2009, p.32).

Carbon Dioxide Equivalent (CO_2e)Emissions: “The amount of CO_2 emission that would cause the same radiative forcing as an emitted amount of a well mixed greenhouse gas, or a mixture of well mixed greenhouse gases, all multiplied with their respective Global Warming Potentials to take into account the differing times they remain in the atmosphere” (IPCC, 2007, p.812).

Carbon Sequestration: “Carbon storage in terrestrial or marine reservoirs. Biological sequestration includes direct removal of CO_2 from the atmosphere through land-use change, afforestation, reforestation, carbon storage in landfills and practices that enhance soil carbon in agriculture” (IPCC, 2007, p. 820).

Direct Carbon Emissions: are onsite emissions directly related to the utilization of materials or inputs. These emissions are “allocated to the end-user sector” (IPCC, 2007, p.814). Direct emissions include but are not limited to the combustion of fuels, chemical transformation of fertilizers, etc.

Emission Factor: “Is the rate of emission per unit of activity, output or input” (IPCC, 2007, p.814).

Upstream or Indirect Carbon Emissions: Are the emissions released during the extraction and refinery of fossil fuels, mining and manufacture of fertilizers, agrochemicals and processing of other materials.

Offset credit: “A carbon credit that has been generated from CO_2e emissions reduction projects” (Williams *et al.*, 2009, p.32).

MEASUREMENT AND CONVERSION UNITS

Measurement Units

C = Carbon

CE = Carbon equivalent

CO_2e = Carbon dioxide-equivalents

Ton CO_2e acre^{-1} yr^{-1} = tons of carbon dioxide equivalents per acre per year

Mt CO_2e ha^{-1} yr^{-1} = metric tons of carbon dioxide per hectare per year

Conversion Units

1 unit carbon equivalent (CE) = 3.67 units of carbon dioxide equivalent (ratio of molecular weight carbon dioxide/ carbon = 44/12)

1 ton (T) = 0.9072 metric tons (Mt)

1 pound (lb) = 0.4535 kilograms (kg)

1 kg = 2.2046 lbs

1 MCF = 1 thousand cubic feet (1,000 ft^3)

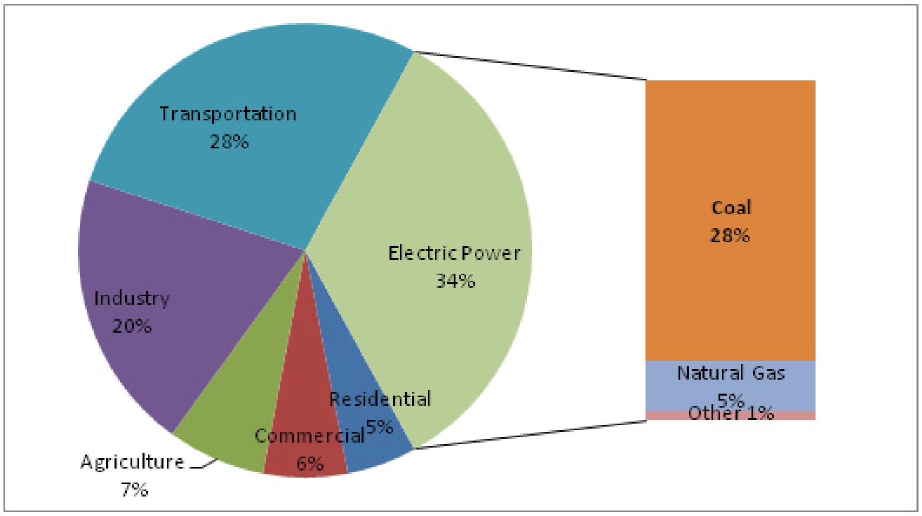
CHAPTER 1 – INTRODUCTION

1.1 Background

1.1.1 Greenhouse gas emissions

Greenhouse gas (GHG) emissions and their possible adverse impacts on the environment is a growing concern in rural America.[1] Agriculture is responsible for 10-12% of total global anthropogenic GHG (Smith *et al*., 2007a). Agriculture is an important sector in the United States economy with approximately 20% of land employed for crop production (U.S. EPA, 2009d).

Figure 1.1 Greenhouse gas emissions in United States in 2007



Source: U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2007

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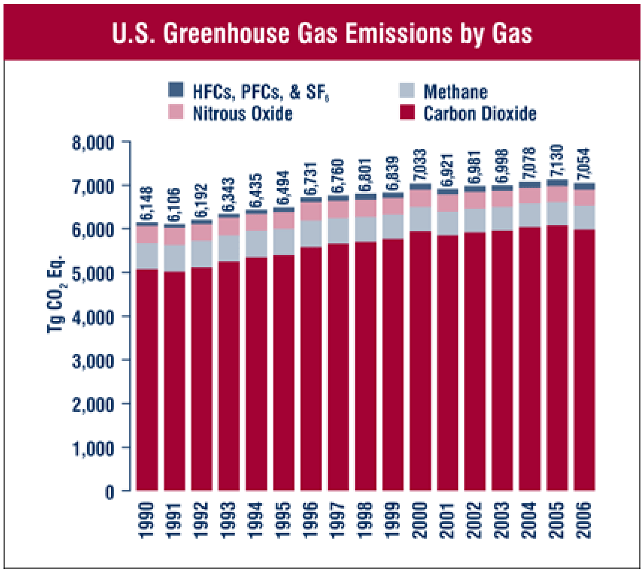
[1] There are some scientists and other experts who are skeptical about the causes of climate change and the relative role of anthropogenic GHG. This study assumes that GHG due to human activity has made an impacting contribution to climate change.

In the United States, agriculture accounted for 7 % of total GHG in 2007 as seen in Figure 1.1. Other sources of emissions are transportation, industry and electricity generation. Emissions from the electric power sector are mainly generated as result of the combustion of fossil fuels like coal and natural gas.

In Kansas, the agricultural sector is responsible for 23.1% of the total GHG emissions, which amounts to 1.49 % of the total emissions within the United States (World Resources Institute, 2010).The estimated GHG intensity of economy (an indicator of GHG emissions per unit of economic output or Gross Domestic Product) for Kansas in 2005 was 1,144.9 Mt CO_2e million US^{-1} (metric tons of carbon dioxide equivalent per million dollars), ranking 24th when compared with other states (World Resources Institute, 2010).

Figure 1.2 U.S. Greenhouse gas emissions by gas



Source: U.S. EPA, U.S Gas Inventory

Approximately 85% of total GHG in the United States are emissions of CO_2 (Figure 1.2). Often, GHG emissions are reported in terms of carbon dioxide equivalent (CO_2e) emissions. Measure of equivalent emissions of carbon dioxide results in a quantification that includes not only carbon dioxide but also other GHG converted to comparable units of carbon dioxide through their Global Warming Potentials. Global Warming Potential is a measure of the contribution from a ton of a specific gas to global warming compared to one ton of carbon dioxide, over a 100 year period.

Nakicenovic *et al*. (1998) argue that global CO_2 emissions could almost double in the next three to four decades. Brennan (2009) points out that the scientific community agrees that the concentration of CO_2 in the atmosphere has an impact on climate change and that emissions must be mitigated. Consequently, the importance of carbon emissions resides with their implications concerning climate change and the associated costs. Yohe *et al.* (2007) suggest that climate change will likely result in net costs into the future especially for regions with less capacity to adapt. They point out that the mean for social cost of carbon emissions (economic and non-economic impacts) in the literature is estimated to be US$43/ton of carbon. According to Easterling and Apps (2005), the consequences of climate change on the agricultural sector could lead to variations in global income and food prices. Agriculture might be affected by climate change due to variability and increases in temperature, changes in rain patterns, and a higher likelihood of drought occurrence (U.S. EPA, 2009b).

Agriculture is an environmentally critical sector due to the existence of a variety of options for GHG abatement. McCarl and Schneider (2001) list three ways in which agriculture can play an important role in GHG cuts. These include: i) reduction of direct GHG emissions, ii) production/use of biofuels and iii) soil carbon sequestration (Nartova, 2008; Lal *et al*., 1998). Crops have the potential to sequester carbon from the atmosphere through photosynthetic processes during production of above and belowground biomass (Smith *et al*., 2007b). Organic carbon from plant material can be stored in the soil for a extended period of time depending on agricultural practices (tillage vs. no tillage), climate conditions, soil properties, etc., (Schahczenski and Holly, 2009). No-tillage systems have been found to have higher carbon sequestration rates and reduced fossil energy use (Kim *et al*., 2009) due to lower fuel consumption associated with machinery operations (McCarl and Schneider, 2001). According to Smith *et al*. (2007a), reduction of emissions in agriculture are more cost competitive than non-agricultural options. Thus, as Nartova (2008, p.11) points out "agriculture and forestry will have to play a role in reducing carbon emissions". Efforts to reduce emissions in the agricultural sector require active participation of individual farmers and different organizations such as farmer associations, agribusinesses and retail operations.

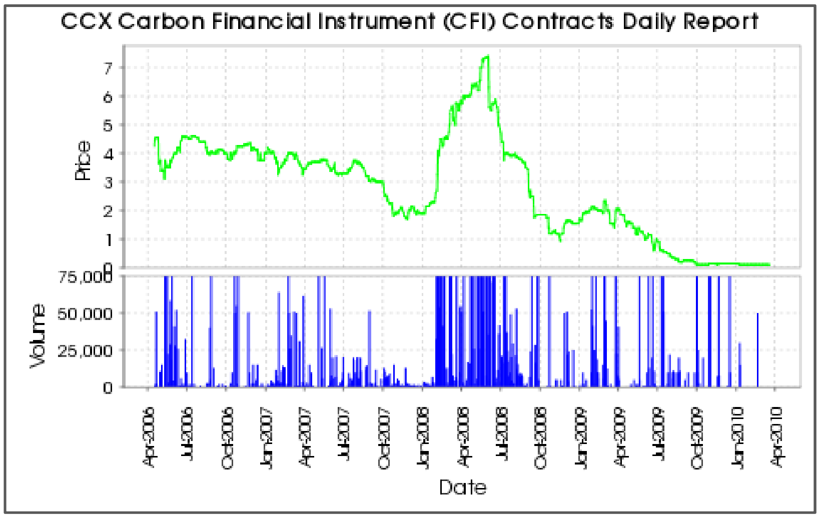
1.1.2 Cap and trade

Currently, environmental policies to regulate GHG are in place in different countries. An example of a well established cap and trade program is the European Union Emission Trading Scheme (EU ETS) created to aid their members in complying with regulations under the Kyoto Protocol. Country members of the European Union, Iceland, Liechtenstein and Norway form part of this program (European Commission, 2010). As legislation continues to address climate change globally, regulations concerning GHG are expected to increase in the future.

Currently in the United States there is a voluntary carbon credit market and trading system called the Chicago Climate Exchange (CCX). Members of the CCX commit to reduce their emissions to a certain level. If the members more than accomplish the target reduction they are able to sell the extra allowances, but if their emissions are over the target they need to purchase credits from project based offsets (Chicago Climate Exchange, 2010). Under the CCX, there is an opportunity for agricultural carbon emissions offsets. Agricultural practices that account for credit generation are conservation tillage systems, grassland and tree planting. Conservation tillage and grassland are considered to generate from 0.2 to 0.6 Mt CO_2 $acre^{-1}yr^{-1}$ and from 0.4 to 1.0 Mt CO_2 $acre^{-1}yr^{-1}$, respectively (Chicago Climate Exchange, 2009).

The historical CCX carbon offset prices from 2006 to 2010 are shown in Figure 1.3. Carbon offset prices show a downward sloping trend with a price boost in 2008. Increases in carbon offset demand and prices during 2008 were likely attributable to climate legislation initiatives by President Barack Obama, the debate of the Lieberman-Warner bill (America's Climate Security Act) and discussion of other climate legislation. Nonetheless, prices have declined over the past couple of years, arguably because of the downturn in the global economy. In addition, problems with the legitimacy of the carbon trading market which arose from the suspension of one of the largest auditors of clean energy projects (Everett and Murray, 2010). In the EU ETS a fall in carbon credit prices was also experienced due to the over allocation of allowances and the resulting excess supply (Williams *at al.*, 2009). Climate legislation is expected to expand carbon credit markets as policies and market regulations are established.

Figure 1.3 Carbon offset prices (US$/Mt CO_2) in the Chicago Climate Exchange



Source: CCX, Carbon offset market data. http://www.chicagoclimatex.com

In the United States, efforts have been made in relation to climate legislation. H.R. 2454, the American Clean Energy and Security Act (Waxman-Markey Bill) of 2009, was passed by the U.S. House of Representatives on June of 2009. The main objective of this bill is to mitigate climate change by dealing with GHG emissions and renewable energy technology. GHG emissions will be limited and reduced over time. A cap and trade system will be developed in order to achieve emission reduction goals (83% of 2005 levels) by 2050. This cap and trade program does not directly limit the quantity of emissions. GHG emissions are expected to decrease gradually by lowering the amount of allowances issued over time (U.S. Senate, 2009).

Under the HR. 2454 bill the government would distribute allowances and companies will obtain a certain amount of permits. Industries emitting GHG over their allocated allowances will have the opportunity to purchase carbon credits from an open market (e.g., companies with lower emissions and carbon sequestration projects, etc) as an offset. On the other hand, companies with emissions below their allowances will be able to sell their permits. This situation represents an economical incentive for companies to reduce their emissions as it opens an opportunity for the creation of an open credit market where companies will be able to trade offsets and allowances. It is also expected to incentivize companies toward more environmentally sustainable systems of production as the development of new clean technologies takes place and new forms of renewable energy become available.

Cap and trade systems have been previously used in the United States to regulate pollutants such as lead, chlorofluorocarbons (CFCs) and sulfur dioxide. As Dunham (2000) states, cap and trade regulations have been effective in reducing air pollutant emissions. In the European Union, there is an Emission Trading System (cap and trade program) that has been in place specifically for carbon dioxide emissions since 2005. This program does not regulate small business or direct a company's usage of fuel (Burtraw and Evans, 2009).

It has been suggested that under a carbon cap and trade program in the United States, companies with emissions above 25,000 Mt yr^{-1} would be subject to regulation (Dennison, 2010). Over time, different versions of proposals have been introduced. Some of them suggested capping emissions upstream (i.e., oil and energy industry) and transferring part of the regulation cost via the final energy price (Stavins, 2007). Others proposed an emission cap downstream or an upstream-downstream combination (Revelle, 2009). For a legislation restricting emissions downstream, some proposals suggested a cap of 10,000 tons of CO_2 (Paltsev *et al*., 2007). However, the H.R. 2454 bill indicates that covered entities will be any electricity generator, producer, importer, or distributor of fuels for which combustions emit 25,000 Mt CO_2e and other industrial sectors (e.g., petroleum refinery, lime manufacturing and cement production, etc) (U.S. Senate, 2009). This is an important number since it sets a threshold level above which companies would become reporting entities and thus their emissions would become regulated.

Nonetheless, regardless of the company's nature, it is important to become acquainted with climate legislation. Companies have different options if they wish to estimate their level of carbon emissions. Currently, there are organizations that can estimate a company's carbon footprint, ecological footprint or can compute a product's life cycle. As Nartova (2008) points out, much progress has been made concerning initiatives of companies to measure their GHG emissions. Many companies might not be subject to climate legislation at this point. However, this is not an assurance that their emissions will not be restricted in the future. Companies might need to start evaluating ways to lessen their emissions and adopting low carbon technologies. This can be beneficial not only from a cap and trade prospective, but also from a marketing standpoint. There is a growing market for environmentally friendly products. People in many parts of the world are willing to pay premium prices for products with environmental attributes (Saunders, 2009; Michaud, 2008). If the H.R. 2454 bill is enacted, a program will be created where carbon content disclosure will be voluntary and an assessment will be conducted by the U.S. EPA to determine if the creation of a national program to measure and report carbon content in labels is feasible (U.S. Senate, 2009). Moreover, with this climate legislation in place, a public outreach program will be developed. Hence, if public awareness increases, it is possible that appreciation for environmental attributes may also increase.

1.1.3 Implications of cap and trade for agriculture

There are different implications for climate legislation in agriculture. Currently, there are different opinions on whether agriculture will benefit or not from a cap and trade program to regulate GHG emissions. Some studies suggest an increase of production costs caused by an increase in input prices (Babcock, 2009; Taylor and Koo, 2009). Notwithstanding the cost increases, there is an opportunity for agriculture to gain from this legislation. The agricultural sector has the potential to sell offsets originating from carbon sequestration in cropland production, especially in no-tillage production systems. U.S Environmental Protection Agency (U.S. EPA, 2009a) suggests that by 2020, as result of cap and trade, conservation tillage and no-tillage production will rise by 50% (considering offset prices as high as \$50 ton^{-1} CO_2). A preliminary analysis of the effects of H.R. 2454 conducted by the U.S. Department of Agriculture (2009) presents evidence showing that decreases in agricultural short-run income due to higher costs will be small and that profits from agricultural offsets may compensate for those higher costs. This study also shows that in the medium and long-run, gains may surpass costs.

A study carried out by FAPRI (2009) on the effect of higher energy prices on forecast of corn production costs indicates an increase by 2050 of 3.2% and 8% in corn and soybeans, respectively. Taylor and Koo (2009) carried out a site-specific study in which they evaluated the impact of climate legislation for North Dakota agriculture. They demonstrated that with a carbon sequestration program, agriculture could have a higher net income compared with a scenario excluding carbon sequestration. Furthermore, their findings suggest that with carbon prices of \$20 to \$35, the increasing input costs could be offset by the gains under cap and trade.

There are several studies that propose different options for the establishment of a cap and trade program. According to McCarl and Schneider (2001), a program offering farmers and landowners different choices is more likely to be accepted by farmers. Choices might include incentive programs to increase carbon sequestration and adoption of soil conservation systems, fertilization management and reduction of fossil fuel use among others. As previously shown, sequestration in agriculture might be directly related to economic incentives (i.e., carbon credit prices and costs). Consequently, as McCarl and Schneider (2001) show, sequestration is reduced at a higher cost and lower carbon credit prices.

As McCarl and Schneider (2002, p. 136) mention, “Agriculture may find itself operating in a world where commodity and input prices have been altered by GHG related policies”. Additional costs imposed on energy providers will indirectly affect production costs in agriculture. Understanding how possible increases in input prices would influence production is valuable. Producers can then make decisions to mitigate the economic consequences of carbon legislation by improving production efficiency, utilizing renewable energy options and generating offset credits.

It is also essential for the agricultural sector to be attentive to the role agriculture plays in climate legislation. Awareness of carbon emission levels from the operation of the agricultural sector can be valuable for decision-making purposes and for the evaluation of possible offsets that could be traded and additional income generated as a product of carbon cap and trade legislation.

The H.R. 2454 bill lists some practices to be considered for offsets in agriculture. These practices include: reduced tillage practices, winter cover crops, reductions in nitrogen fertilizer use, grassland management and manure management. Adoption of any of those practices will benefit the agricultural sector by creating an alternative source of income.

1.2 Justification

This study focuses on evaluating GHG emissions by agribusiness retailers in Kansas. Agribusiness retailers are an important business in the rural economy. They provide agronomic, financial credit, energy, feed, and fertilizer inputs to producers. They also provide a variety of agricultural services for their farmer members. These services usually encompass custom machinery operations, agrochemical applications and feed processing. These retail agribusiness firms function not only as input and resource suppliers but also as marketing units for farm products. Many of these retailers are cooperatives that are owned by producers.

In this study GHGs emissions from eight agribusiness firms were evaluated. It is important for these retailers to know their emissions level for a number of different reasons. Even though agricultural GHGs emissions will not be restricted under the current R.H. 2454 bill, future policy modifications could regulate GHGs emissions from agronomic operations. Thus, if these retailers were subject to regulation, it may be possible for the members to provide any offsets that these retailers might require by law. Longer term, the members might ask the cooperative to market their offsets just as they market their crops.

Additionally, knowing the carbon emissions produced by a retailer can be advantageous if they desire to identify the major sources of their emissions and the specific places they will need to address if they plan to get involved in emissions reduction programs.

No information is available on the extent of CO_2 emissions emitted by these retailers. This study is the first to analyze that impact on agricultural retailers.

1.3 Research objectives

The objective of this study is to evaluate carbon emissions from eight agribusiness retailers. The specific objectives include:

1. Estimate carbon dioxide equivalent emissions from the operation of agribusiness retailers. Emissions are from the use of energy inputs to operate office buildings, grain elevators, equipment, vehicles and other machinery and equipment.
2. Estimate the cost associated with different levels of emission reductions. Reductions levels are based on the retailers' current emissions and the cost was determined using future carbon prices found in the literate.

Carbon emissions are calculated utilizing data from energy inputs utilized in the operation of the agribusiness retailers. Emissions are obtained by employing carbon emission factors. Carbon emissions are computed as carbon dioxide equivalents. Total (direct + upstream) emissions are calculated from the retail activities. Total emissions encompass direct emissions or emissions from the extraction, generation, refining of materials/ energy inputs and upstream emissions or emissions originating during combustions of fuels and chemical transformation of the materials.

1.4 Thesis overview

The next chapter discusses previous literature on the topic and how this study contributes to that knowledge. Chapter 3 describes the data source employed in this study and the methodology used is described in Chapter 4. Chapter 5 provides the results from this study and the conclusion and recommendations are presented in Chapter 6.

CHAPTER 2 – LITERATURE REVIEW

2.1 Carbon footprint

The previous chapter described global concerns about climate change and the consequent need to measure GHGs emissions was discussed. To date, there is some variation in the definition of a carbon footprint. In addition to CO_2, some include in the calculation emissions of other gases with greenhouse warming potential. Other studies express emissions on an area basis (e.g. hectares, acres, etc). Nonetheless, the key point when defining a carbon footprint is the measure of CO_2 equivalent emissions associated with all the activities throughout the life cycle of a product or a process (POST, 2006; ETAP, 2007). Wiedmann and Minx (2007, p.4) proposed the following definition: "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that are directly and indirectly caused by an activity or is accumulated over the life stages of a product." Wiedmann and Minx state very clearly the importance of including both direct and indirect emissions when estimating carbon footprints. Some of the variants and associated advantages and disadvantages when measuring carbon emissions are presented in Table 2.1.

Table 2.1 Various carbon measures

Various Carbon Emissions Estimation Procedures	Advantages	Disadvantages
Inclusion of upstream/downstream emissions	• It allows evaluating emissions throughout the entire life cycle of a product or process.	• A double counting problem can be encountered when the same emissions are reported by different entities involved in the process or product's life. This gives rise to inaccuracies when related systems are analyzed due to overlapping of emissions (Lenzen, 2008).
Inclusion of emissions other than carbon dioxide (substances with greenhouse warming potential)	• A more complete measure. It constitutes more than a carbon footprint; a climate footprint (Wiedmann and Minx, 2007).	• Quantification becomes more difficult due to data availability. • Results in a combined indicator of gases that is less comprehensive because it gives a weight of carbon from not only substances with carbon in their molecule but also without (Wiedmann and Minx, 2007).
Emissions expressed on an area basis	• It can be more convenient for some comparison purposes.	• Conversion of emissions to an area basis constitutes a source of uncertainty and error (Lenzen, 2006).

Under the HR 2454 bill, a carbon footprint is considered “the level of greenhouse gas emissions produced by a particular activity, service, or entity” and the term carbon lifecycle means “greenhouse gas emissions that are released as part of the processes of creating, producing, processing or manufacturing, modifying, transporting, distributing, storing, using, recycling, or disposing of goods and services” (U.S. Senate, 2009).

Numerous studies have quantified GHG emissions associated with the production of agricultural products. To date, any research has been conducted to estimate the emissions from further steps in the value chain for agricultural products. Agribusinesses in this study function as both input suppliers and retailers constituting an important element in the agricultural sector. Some of the studies looking at emissions from crop production are presented here because of the importance of the studied crops for these agribusinesses.

2.2 Carbon dioxide emissions from agricultural production

Several studies have estimated carbon emissions from agricultural production. Most of these studies have utilized input data from Cooperative Extension Service budgets. The great majority of these studies have quantified direct emissions released from the utilization of inputs and fuels, as well as, embodied emissions from the extraction and manufacture of agricultural inputs and energy.

In a study conducted by Nelson *et al*. (2009), direct and embedded energy and CO_2 emissions were estimated for nine crops and three tillage intensities in the United States. They found total emissions from cropland production vary across systems. Reported emissions were as low as 91 kg C ha^{-1} yr^{-1} (297 lb CO_2 $acre^{-1}$ yr^{-1}) and as high as 365 kg C ha^{-1} yr^{-1} (1194 lb CO_2 $acre^{-1}$ yr^{-1}). Their findings suggest that no-till systems have lower CO_2 emissions than other tillage practices. Similarly, a study by Clayton-Niederman *et. al.* (2010) employed a Life Cycle Assessment (LCA) to estimate carbon equivalent emissions from the production of cotton in 16 states across the United States. They determined emissions from 80 productions systems and compared emissions across different systems. They reported 415 kg C ha^{-1} (1358 lb CO_2 $acre^{-1}$) as weighted average carbon emission for cotton production in the US and a yield-based carbon emission of 0.41 kg CE/ kg cotton (1.5 lb CO_2/ lb cotton) in 2007.

Williams *et al*. (2004) quantified carbon emission and soil carbon sequestration for continuous and rotation wheat and grain sorghum in Kansas, in order to determine carbon credit values. Emission values ranged from 0.111 Mt C ha^{-1} yr^{-1} (0.182 ton CO_2 $acre^{-1}$ yr^{-1}) in conventional-till continuous wheat to 0.1624 Mt C ha^{-1} yr^{-1} (0.2608 ton CO_2 $acre^{-1}$ yr^{-1}) in no-till continuous wheat.

Other studies (Pendell *et. al*., 2007 and 2006b) have looked at carbon emissions and sequestration from corn production under different cropping systems in Kansas. Carbon emissions in corn under conventional tillage were higher than those for no-tillage. Pendell *et al*., (2006a) reported similar conclusions in a study with a grain sorghum-soybean rotation. Their results indicated that direct and total emissions from conventional tillage systems were the highest, whereas no-till systems had the lowest direct emissions.

Studies evaluating CO_2 emissions in agriculture have also been conducted in other countries. Harris-Adams and Kingwell (2009) calculated GHGs emission for livestock, crop and pasture production in Australia. In their study, nitrogen fertilizers were identified as one of the most relevant sources of GHGs emissions in regions with crop dominance. This study did not account for fuel utilization. Likewise, Saunders (2009) showed that fertilizers are the most significant source of emissions in agricultural production in the United Kingdom and New Zealand. A summary of various studies addressing carbon emissions is presented in Table 2.2.

Table 2.2 Literature dealing with carbon emissions in crop production

Study	Location	Crops	Scenarios	Data	Measures	Strengths	Limitations
Nelson *et al*. (2009)	United States at a county scale	Corn, soybean, wheat, sorghum, barley, oat, rice, cotton and hay.	Conventional, reduced and no-tillage systems	Independent survey data, national inventory data and operational budgets.	Direct, upstream and total CO_2 emissions from crop production	• County level estimates based on individual management practices. • Estimations of energy use.	• Does not account for nitrous oxide (N_2O) from the application of nitrogen fertilizer.
Saunders (2009)	New Zealand and United Kingdom	Apples and onions (it also includes calculation of emission from production of dairy and lamb)		Production budgets, surveys, reports and other literature sources	Direct and upstream emissions from common inputs in agricultural production between NZ and UK and export transportation from NZ to UK.	• Estimated emission per unit of output. • Determine emissions from capital inputs (machinery, implements and buildings). • Estimations of energy use.	• Does not account for nitrous oxide (N_2O) from the application of nitrogen fertilizer. • Does not account for internal transport, it just account for export transport.

Study	Location	Crops	Scenarios	Data	Measures	Strengths	Limitations
Clayton-Niederman *et al*. (2010)	Cotton	358 counties in the United States	80 practices (irrigation and tillage practices, seed type, etc)	Production budgets. National Agricultural Statistics Service (NASS)	Direct and indirect carbon equivalents from cradle to farm gate.	• Assessed of GHGs efficiency per unit of cotton output • Estimation of variability and uncertainty of carbon emissions	
Kim *et al*. (2009)	Corn grain and corn stover		Tillage practices across different locations in the US Corn Belt	Inputs use from the NASS and fuels consumption from the Economic Research Service	County level estimates of environmental performance (life cycle assessment)	• County level modeling • Estimation of environmental performance	• Some county level data not available
Pendell *et al*. (2006b)	Manhattan, Kansas	Corn	Conventional and no-tillage systems with two rates of nitrogen from ammonium nitrate or cattle manure	Experimental field data	Direct, upstream and total CO_2 emissions from crop production	• Based on experimental work. Input use from real field data. • Estimated carbon sequestration and monetary value of credit incentives.	• Does not account for carbon emissions originated from methane in the use of manure nor nitrous oxide releases from the soil

Study	Location	Crops	Scenarios	Data	Measures	Strengths	Limitations
Williams *et al*. (2004)	South central Kansas	Continuous and rotation wheat and grain sorghum	Conventional and no-tillage systems	Experiment station data	Direct, upstream and total CO_2 emissions from crop production	• Estimated carbon sequestration and carbon credits	• Experiment may have used more herbicide and tillage than farm manager would.
West and Marland (2002)	United States	Corn, soybean and wheat	Conventional, reduced and no-tillage systems	US average crop inputs Literature	Carbon emission from agricultural production and carbon sequestration rates with a change from conventional tillage to no-tillage	• Model carbon flux to the atmosphere • Included emissions during the transportation of inputs. • Detailed estimations and assumptions	• Based on average crop inputs. • It is not site-specific. • Does not account for nitrous oxide (N_2O) from the application of nitrogen fertilizer

2.3 Summary

This chapter looked at various carbon measures and at different studies researching carbon emissions in agriculture and also main sources of emissions from crop production. These studies have been done at an agricultural production level. No study has been done looking at retail agribusinesses that provide services to agricultural producers. This study contributes to this literature by analyzing emissions of retail agribusinesses. The next chapter describes the data and data sources employed in this study.

CHAPTER 3 - DATA

3.1 Agricultural and energy inputs

Data from 2007 and 2008 was collected for eight agribusiness retailers in Kansas. All retail operations in the state were invited to participate in this study in November of 2009. The eight retailers used in this thesis had complete information. The retailers' information was kept confidential and was treated anonymously. For this reason they are referred to as Retailers A, B, C, D, E, F, G and H. These agribusiness retailers function as input suppliers (i.e. agrochemicals, fertilizers, seeds and fuels), service providers (i.e. credit and consulting services, custom fertilizer and chemical applications, grain transportation and grain elevators) and marketing units. These firms served approximately two million acres of conventional and no-tilled corn, grain sorghum, wheat, soybeans, alfalfa-hay, brome-hay and sunflower. Of the total acreage served, wheat accounts for 68% of the total followed by soybeans with 14% and corn with 9%.

Sources of carbon emissions from energy consumption by these retailers are shown in Figure 3.1. Data corresponds to the energy used by office buildings (e.g., electricity), vehicles (e.g., trucks, semi trucks, cars, agronomy equipment and others using energy), grain elevators (e.g., energy, electricity) and other operations. The eight retail operations encompass over 100 locations with a grain elevator, fertilizer plant, feed plant or bulk plant.

Figure 3.1 Sources of carbon emission from agribusiness retailers in Kansas

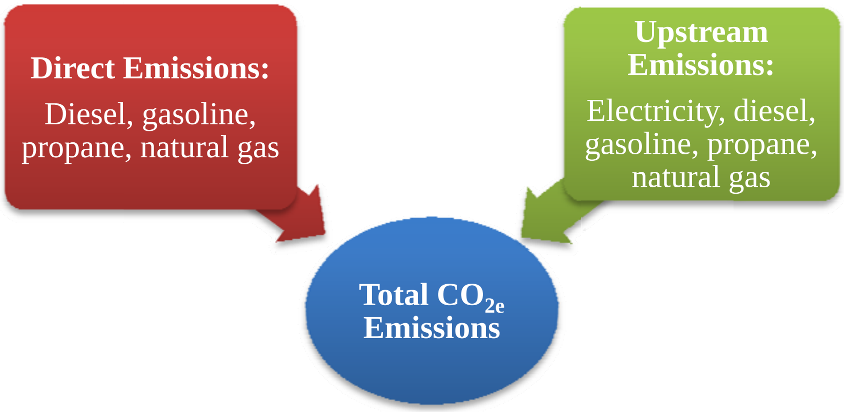


Table 3.1 shows the mean and standard deviation for energy consumption for retail operations. The mean and standard deviation in 2007 are higher than in 2008.

Table 3.1 Mean electricity and fuel consumption across retail operations, 2007-8

Year 2007	Mean	Maximum	Minimum	Standard Deviation
Electricity[a]	3,307,877	19,774,646	11,234	7,278,393
Diesel[b]	91,936	294,796	4,321	95,707
Gasoline	13,891	25,865	4,431	7,078
Natural Gas[c]	76	478	0	178
Propane	607	4,250	0	1,606
Ethanol	136	949	0	359
Year 2008	Mean	Maximum	Minimum	Standard Deviation
Electricity	613,935	1,434,260	12,987	535,542
Diesel	75,930	135,611	4,456	49,252
Gasoline	13,385	22,276	3,987	7,337
Natural Gas	130	712	0	287
Propane	1,191	5,670	0	2,272
Ethanol	0	0	0	0

[a] Electricity is expressed and kWh units.
[b] Diesel, gasoline, propane and ethanol are expressed in gallons.
[c] Natural gas is expressed in MCF.

This result occurs because 2008 data does not include Retailer E (due to lack of data) which is the largest retailer in terms of dollar assets. Maximum and minimum values are also presented.

3.2 Carbon emission factors

Carbon emission factors were used to estimate carbon emissions from direct inputs. Downstream and upstream emissions were determined for the operation of the agribusiness operation. Direct emission factors used for diesel and gasoline were obtained from the Environmental Protection Agency (2005) and from Deru and Torcellini (2007) for propane and natural gas. Upstream emission factors from gasoline and diesel were obtained from Ecoinvent databases (Ecoinvent center is a life cycle inventory data provider). This information was provided by Zara Clayton-Niederman and Dr. Lanier Nalley at the University of Arkansas. A network of different processes involved in gasoline and diesel emission factors are shown in Figure 3.2 and Figure 3.3. These networks provide insight into how emissions factors are estimated and the emission sources that to contribute to the total emissions per unit of fuel. For fossil fuels, processes that release emissions include extraction, refinery, ocean transport, electricity, oil fuel and natural gas combusted in industrial boilers, and combustion of the fuel by the end consumer. On the other hand, for the purpose of this study it was assume that fuels from ethanol are carbon neutral because their emissions could be offset by the sequestration of carbon throughout biomass growth (U.S. EPA, 2009c). [2]

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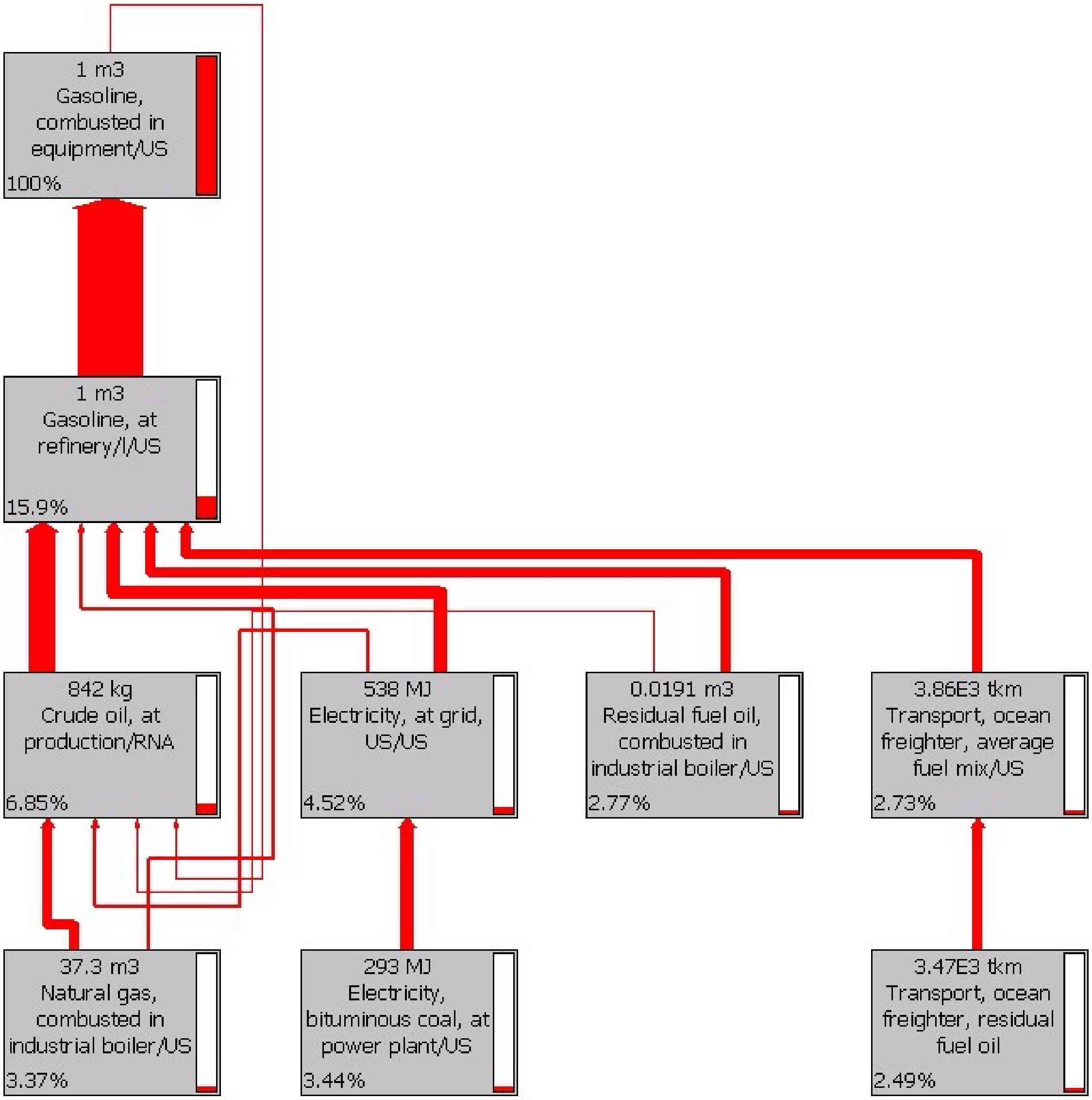
[2] Some studies have argued otherwise. However proposed carbon dioxide emission values from ethanol differ among studies, based on their assumptions (Shapouri *et al.*, 2003).

Figure 3.2 Network of gasoline process and sources of GHG emissions allocation[3]



Source: SimaPro LCA software.

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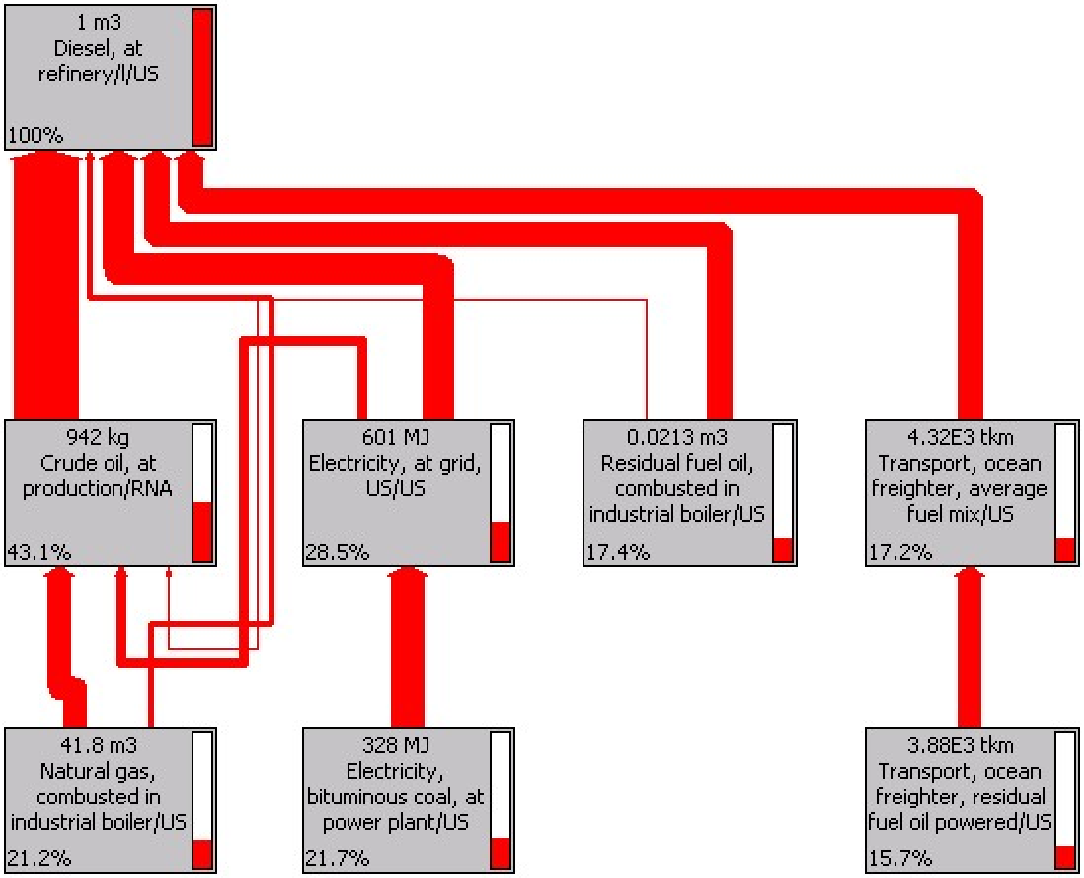
[3] The network shows the quantity of energy inputs, from different processes, per unit of gasoline (1 m^3). Carbon dioxide-equivalent emissions are released from each of these processes.

Figure 3.3 Network of diesel process and sources of GHG emissions allocation[4]



Source: SimaPro LCA software.

Emissions from electricity originate off-site of the retail operation from the fuels employed in power generation. The emission factor for electricity employed here encompasses 1.68 lb CO_2e kWh^{-1} for electricity generation in Kansas (U.S. Department of Energy, 2002) and 0.056 lb CO_2e kWh^{-1} from the production and transport of fuels (West and Marland, 2002).

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[4] The network shows the quantity of energy inputs, from different processes, per unit of diesel (1 m^3). Carbon dioxide-equivalent emissions are released from each of these processes.

Emissions from the manufacture of farm machinery and vehicles were not accounted for in this study, because they are assumed to be reasonably small once the emissions are amortized over the lifetime of the equipment or machinery. Similarly, energy employed in the construction of buildings is not included here.

Table 3.2 Direct and indirect carbon dioxide emission factors

Electricity and Fuels	Direct		Upstream	
	lb CO_2 / unit	kg CO_2 / unit	lb CO_2 / unit	kg CO_2 / unit
Electricity (kWh) [a]	---	---	1.73	0.788
Natural Gas (MCF) [b]	122.99	55.79	27.80	12.61
Propane (gallon)	13.49	6.12	2.56	1.16
Gasoline (gallon)[c]	19.40	8.80	4.36	1.98
Diesel (gallon)	22.26	10.10	3.48	1.58

[a] Emissions from electricity include emissions the from the generation of electricity (U.S. Department of Energy, 2002) and the production and transport of fuel (West and Marland, 2002).

[b] Natural gas and propane factors from Torcellini and Deru (2007).

[c] Direct emission factors for gasoline and diesel are from EPA (2005) and the upstream factors are from Ecoinvent.

3.3 Summary

This chapter describes the data from retail agribusinesses in Kansas used in this study and carbon emission factors employed to estimate carbon dioxide emissions from their opeartions. The eight retailers in this study are referred to as Retailer A, B, C, D, E, F, G and H for confidentiality purposes. These firms are marketing, grain, farm supply and service associations. The next chapter discusses the methods used in the study.

CHAPTER 4 – METHODOLOGY

Carbon dioxide -equivalent (CO_2e) emissions were calculated from agricultural processes for retail agribusiness firms in Kansas. Emission quantification in this study includes direct emissions (e.g., fuel combustion, process emissions) and upstream emissions which are emissions released off-site of the retail operation (e.g., extraction and refinery of fuels, emission from energy generation, etc). Carbon dioxide-equivalent emissions are referred to as carbon emissions or just emissions throughout the remainder of the study.

4.1 Estimation of carbon dioxide-equivalent emissions from the retail operations

Emissions from the retail operations were estimated by determining the emissions associated with each energy source (i.e., fuels, gas, electricity) and employing carbon emission factors for both, direct and upstream emissions. That is:

$$CDE_r^D = (E \times EF_E{}^D) + (Gas \times EF_G{}^D) + \sum_i (fuel_k \times EF_i{}^D) \tag{1}$$

$$CDE_r^U = (E \times EF_E{}^U) + (Gas \times EF_G{}^U) + \sum_i (fuel_k \times EF_i{}^U) \tag{2}$$

where CDE_r^D and CDE_r^U represent direct (D) and upstream (U) carbon dioxide emission (CDE) expressed in tons of CO_2 from the operations of the *r*th retailer (r = A, …, H) and *EF* represent the emission factor per unit of input. Emissions from retail operations encompass emissions from the operation of office buildings, stores, grain elevators and equipment to deliver and apply agronomic inputs. These emissions originate from the use of electricity (*E*), natural gas (*Gas*) and each fuel *k* (*k* = gasoline, diesel, propane).

Consequently total emissions are the sum of direct and upstream emissions as follows:

$$Total\ CDE_r = Total\ CDE_r^D + Total\ CDE_r^U \tag{3}$$

$Total\ CDE$ represents the total burden of emissions associated with the operation of the retailers, which is direct and upstream emissions.

Framework

A log-log transformation was utilized to obtain the elasticity of total emissions with respect to input use. This is a percentage change in the total emissions of a retailer firm given a change in the energy inputs consumed. Ordinary Least Square (OLS) was utilized to estimate the following regression:

$$ln\ CDE = \beta_0 + \beta_1\ \ln(Electricity) + \beta_2 \ln(Fuel) + \varepsilon \tag{4}$$

where $Electricity$ and $Fuel$ (gasoline and diesel) are the average quantities consumed of each energy source by year and are expressed in KWh and gallons, respectively. ε is the error term and β_0, β_1 and β_2 are the parameter coefficients to be estimated. Natural gas and propane were not included here since only two locations used these fuels.

4.2 Estimation of carbon dioxide-equivalent emission reduction costs

The potential cost of emissions reduction was estimated by imposing a price on the carbon dioxide emissions. The cost of the emissions was determined employing projected carbon prices under climate legislation found in the literature. Different scenarios were constructed based on different levels of emission reductions and various estimated future carbon prices. The reduction levels considered in this study were 5%, 10%, 15% and 20% of the total and direct average (2007- 2008) annual emissions. Carbon prices employed were $10, $15, $20, $30 and $50 per metric ton of carbon dioxide equivalents. These carbon prices are in line with a range of prices used in other studies in the literature. U.S. EPA Analysis of the H.R. 2454 estimated carbon prices ranging from $9 to $15 per metric ton in 2012, Babcock (2009) assumes a carbon price of $20 in his analysis of the cost and benefits from climate change policy and the Nicholas Institute of Duke University (NIEPS 2009) considered carbon prices of $15, $30 and $50 per metric ton in their study of the effect of low carbon policy in net farm income.

4.3 Summary

This chapter explains in detail the framework utilized to estimate carbon emissions from the retail operations. Carbon emission factors are employed to estimate total GHGs or carbon dioxide-equivalent from energy input consumption. This result provides the estimate of the retailers’ carbon footprint.

CHAPTER 5 – RESULTS

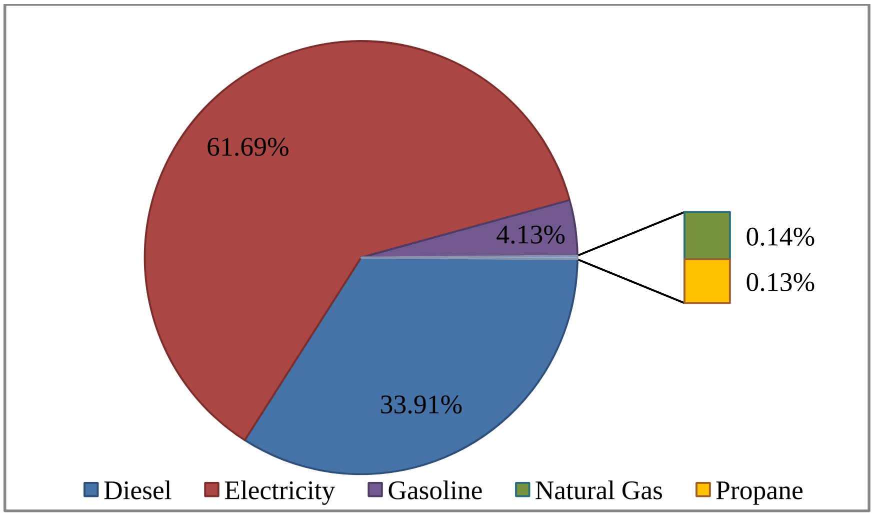
Annual carbon dioxide-equivalent emissions were calculated for each retailer utilizing two years of energy consumption data. Emissions originate from the use of energy inputs from the operation of the agribusiness retailer locations and from the services these retailers offer. Retail operations consist of the operation of the main offices, stores, grain elevators, fertilizer plants, fueling stations and other operations. Some of the services these retailers offer are different farm machinery operations. With estimations of the retailers' annual emissions it was possible to compare their emission level with the threshold suggested under the HR 2454 bill. Results are also presented here for the potential cost of reducing emissions under different scenarios. If retailers had to purchase offset credits, they could do it from their member farmers. Some of the implications are also discussed.

5.1 Sources of carbon dioxide emissions from retail operations

Sources of energy generally used for the retail operations are gasoline, diesel, natural gas, propane and electricity. The percentage distribution of the sources of total and direct carbon emissions is shown in Figure 5.1 and Figure 5.2. The major contributor to total carbon emissions from the retailers' operations is electricity, which accounts to 61.69 % of the total emissions. According to Deru and Torcellini (2007), electricity production in the United States employs principally 71 % fossil fuels as a source of energy. In Kansas coal, natural gas and petroleum represent approximately 80% of the fuel sources for electric generation in 2005 (U.S. Department of Energy, 2008). This implies that a great majority of emissions from agribusiness retailers are directly related to the burning of fossil fuels. The above finding is not surprising. The U.S. EPA (2009c) has estimated that fuel burning is responsible for 94% of 2007 CO_2 emissions in the United States.

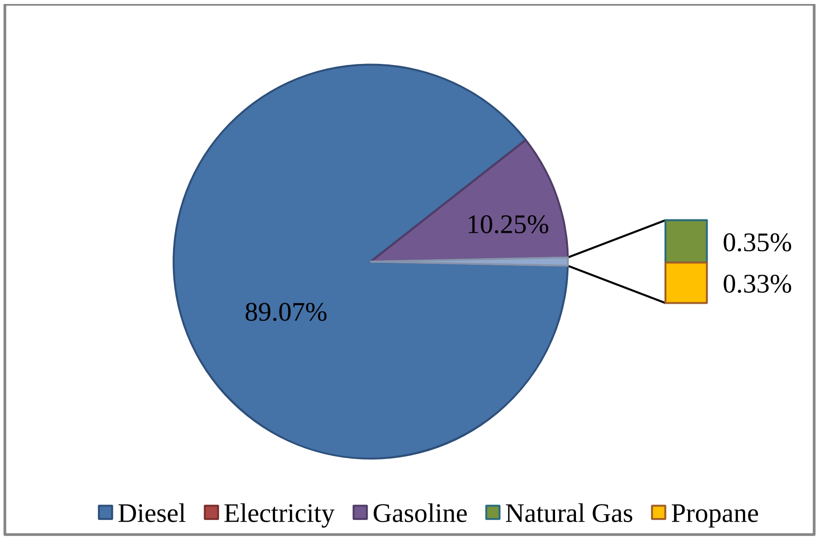
Furthermore, 33. 91% of the emission corresponds from diesel compared to 4.13% from gasoline. Diesel consumption is notably higher than gasoline for all the retailers, except for Retailer D which is the smallest one. This occurs due to the operation of farm equipment and other heavy-duty vehicles, which commonly requires diesel fuel. On the other hand, higher gasoline consumption in the smallest cooperative might indicate they operate less farm equipment and trucks due to less agronomic operations (less acreage being served) and more grain marketing. It is important to note that carbon emissions per gallon of diesel are higher compared to those of gasoline, due to the higher carbon content in the diesel. Propane, natural gas and ethanol also represent, to a lesser degree, a source of carbon emissions. These alternative fuels account for less than 1% of total emissions.

Figure 5.1 Sources of total carbon emissions by agribusiness retailers



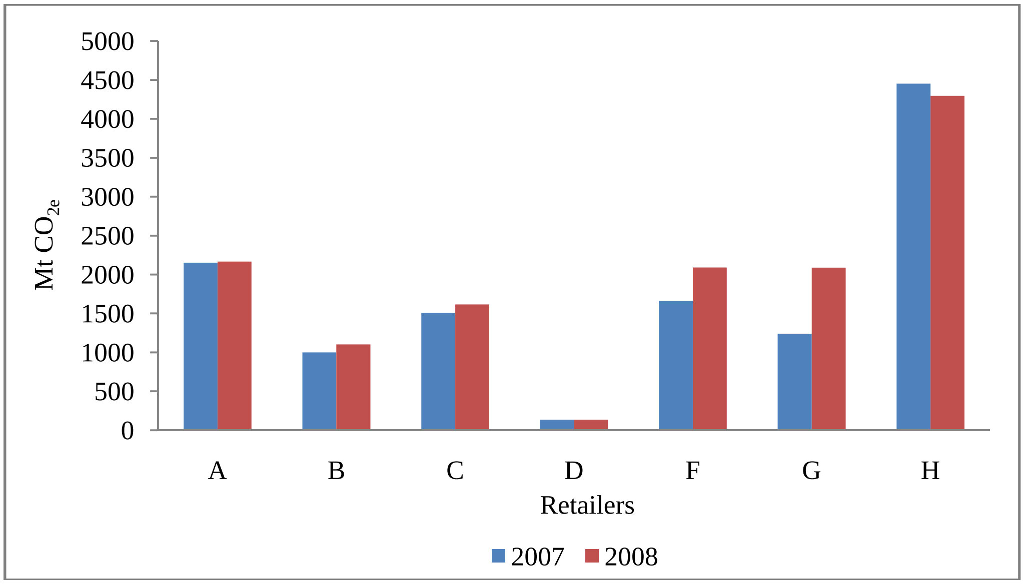
Nevertheless, the main sources of emissions differ when just direct emissions or emissions originated on-site are considered. Electricity is generated from the conversion of other sources of energy such as coal, natural gas, petroleum, nuclear energy and others. Thus, emissions from electricity occur off-site the retail operation during its generation and therefore do not represent an important source of direct emissions. Diesel fuel represents the main source of direct carbon emissions from the retail operation with 89% followed by gasoline with 10.25%.

Figure 5.2 Sources of direct carbon emissions by agribusiness retailers



Results from retailer E are not presented in Figure 5.3 since data for 2008 was not available. Results suggests that, in general, emissions in 2008 were higher than in 2007, with the exception of retailer H, for which emissions were lower and retailers A and D for which emissions did not drastically vary. Increases in total emissions for retailers B and C are mainly related to diesel and to electricity consumption for their respective operations.

Figure 5.3 Total carbon dioxide emissions (2007-2008) by agribusiness retailers



Lower total emissions for retailer H in 2008 are the result of a decrease of 3% and 40% in electricity and gasoline consumption, respectively. Even though, diesel consumption for H increased by 1.2%, the total effect is an overall reduction of 3.32% of total emissions. Retailer A, on the other hand, had higher fuel consumption in 2008 but, a reduction in electricity counteracted this increase. Given the increase in fuel use and decrease in electricity, direct emissions were higher and upstream emissions were lower. Conversely, total emissions from retailer G more than doubled in 2008 as a result of an increase of 123% in diesel use compared to 2007. This could have been caused by an expansion of operations and acquisition of vehicles and equipment, among others possible reasons.

Furthermore, increases in total carbon emissions for retailers B, C and F were 10%, 7% and 26%, respectively.

Figure 5.4 Total equivalent carbon dioxide emissions by source (average 2007-08)

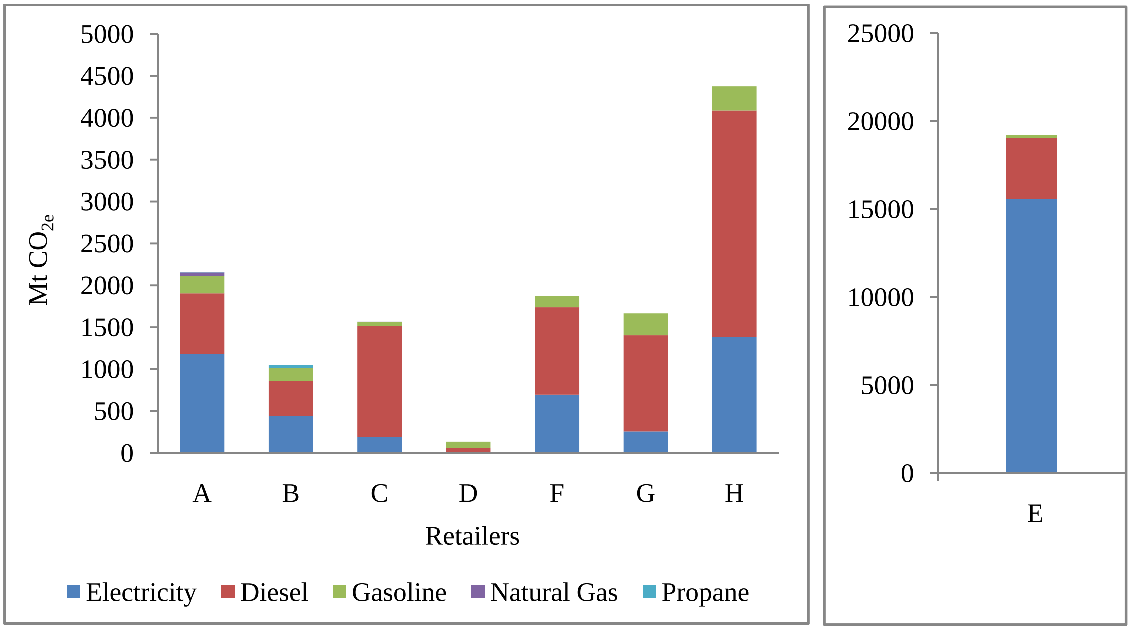
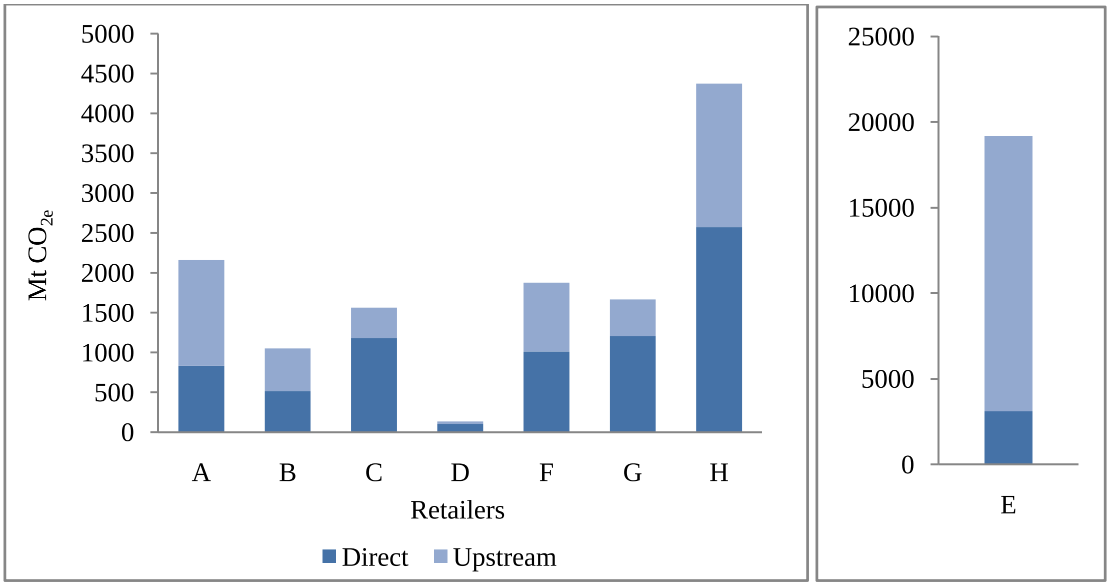


Figure 5.5 Direct and upstream equivalent carbon dioxide emissions (average 2007-08)



Direct emissions represent more than half of total emissions for all the retailers except for Retailers A and E for which electricity represents a main source of energy. For Retailer E, upstream emissions represent 84% of the total emissions. The opposite situation is observed for Retailer D for which diesel is the main source of total emissions and as a result direct emissions represent 77% of total emissions. Despite the fact that Retailer E has total emissions approximately four times higher than Retailer H, its direct emissions are close to Retailer H's direct emissions. This might have implications with respect to the diversification in the operation of the retailers. Retailers with more locations specialized in grain marketing, retail sales and fuel services tend to use more electricity as a main source of energy. If electricity is the main source of energy, retailers have higher total emissions and lower direct emissions (relative to their size) compared to retailers with a strong agronomic service component and higher diesel fuel use.

5.1.1 Carbon emission parameter estimates

Results from equation (4) that estimates changes in total emissions due to changes in energy inputs are presented in Table 5.1. The outcome suggests that a 1% increase in the quantity of fuel used results in a 0.58% increase in carbon dioxide emissions. Similarly, an increase in electricity use by 1%, results in an increase of total carbon emissions by 0.39%. The percentage increase in total emission due to an increase in input is higher for fuel given that the quantity of carbon dioxide release during combustion is higher than the emissions from energy generation.

Table 5.1 Carbon emission parameters estimates

Parameter	Estimate	Standard Error
Intercept	2.47289***	0.52506
Electricity	0.38705***	0.04187
Fuel[a]	0.58048***	0.07946
R-square 0.98		

[a] Fuel includes units of diesel, gasoline or propane.

5.2 Carbon dioxide equivalent emissions from the retail operations

Table 5.2 summarizes direct, upstream and total emissions generated by the retailer operations. Direct emissions are the emissions generated onsite from the use of inputs (e.g., combustion of fuels) whereas indirect emissions correspond to the extraction, processing, refining and transportation of inputs. The retailers have direct control over direct emissions but do not have any control for those emissions occurring offsite referred as indirect or upstream emissions because most of these inputs are imported and the individual retailer does not control over the emissions occurring from extraction, refinery or processing of fuel, fertilizers and other inputs. It is important to know the direct and total emissions to evaluate if the company would be subject to legislation under different alternatives.

If emissions were to be regulated downstream it is unlikely that any of the agribusiness firms in this study would be covered. The threshold for a covered entity under the H.R 2454 legislation is 25,000 Mt and none of the firms have emissions that exceed this quantity. The highest total carbon emissions occur in firm E with total emissions of 19,176 Mt CO_2e yr^{-1}, but is must be noted that this is the sum of all the locations and the 25,000 Mt threshold level corresponds to a single location. Firm E is much larger compared to the rest of the retailers. However, direct emissions in Retail E are 3,103 Mt CO_2e yr^{-1} which is a small number compared to the potential threshold for a cap and trade.

Table 5.2 Carbon dioxide emission (Mt CO_2e yr^{-1}) by retail operation, 2007-08

	2007			2008		
Retailer	Direct	Upstream	Total	Direct	Upstream	Total
A	784	1,368	2,153	882	1,284	2,166
B	479	522	1,001	555	547	1,102
C	1,149	359	1,508	1,213	404	1,616
D	105	30	135	104	31	135
E	3,103	16,072	19,176	---	---	---
F	950	714	1,663	1,077	1,013	2,090
G	841	400	1,241	1,566	523	2,089
H	2,617	1,835	4,452	2,527	1,769	4,296

On-site emissions for the eight retailers average 1,254 CO2e yr^{-1}. This implies that, if agricultural emissions were to become restricted in the future, none of these retailers' operations would be subject to the legislation. Thus carbon dioxide caps would have to be very low for these retailers to be directly affected by a carbon cap and trade since their levels of direct and total emissions are low. The above is especially true if emissions are considered by location, as seen in Table 5.3.

Location-specific emissions were estimated by dividing total emissions by the number of locations each retailer has. Location-specific total emissions average ranges from 120 to 555 ton Mt CO_2e yr^{-1} and for direct emissions ranges from 29 to 383 Mt CO_2e yr^{-1}. The average location-specific emissions are very low and therefore the probability for them to be restricted is low. When comparing the location average emissions across retailers, previous highest and lowest emissions values slightly differ from the totals. For example, when accounting for total emissions, retailer D has the lowest emissions. On the other hand, when location-specific emissions are assessed retailer C has the lowest emissions. However, it is difficult to compare retailers because location size and number of locations are different for all these retailers.

Table 5.3 Average emissions (Mt $CO_2e\ yr^{-1}$) by individual retail location

Retailer	Number of locations	Direct	Upstream	Total
A	139	221	139	360
B	129	134	129	263
C	91	29	91	120
D	105	30	105	135
E	74	383	74	457
F	72	62	72	134
G	401	154	401	555
H	89	62	89	151

5.3 Carbon dioxide-equivalent emissions and retailers size

There is a positive relationship between the size of the retail operation in terms of assets value and carbon emissions (total and direct) from the entire operation. A positive relation is also observed between size and average “total” emissions per location. Larger firms show higher emissions. In contrast, a negative relation is observed between retailers’ sizes and average “direct” emissions per individual location. Larger retailers in this study have more locations and/or higher electricity use and even if total emissions for the total operation are high, direct emissions per location tend to be lower. However comparisons beyond this become difficult due the heterogeneity of the emissions source.

In addition, total carbon dioxide-equivalent emissions relative to each dollar of asset value (lb CO_2e \$ asset $^{-1}$) were estimated for each retail firm except for firm G for which asset value data was not available. No clear relationship between emissions by unit of asset and retailers size was observed. For instance, retailer E is the biggest retailer and its total emissions per unit of dollar asset is 0.25 kg CO_2e \$ asset^{-1}, ranking third from low to high values when compared to the other retailers. Retailer D, the smallest retailer shows the lowest amount of emissions per unit of assets (0.05 kg CO_2e \$ asset^{-1}) due to the nature of its operations. Retailer D is a marketing firm and thus their diesel and gasoline use is low compared to firms with a farming machinery service component. Retailer A, has a kg CO_2e \$$^{-1}$ asset ratio of 0.50 arguably given the high level of diesel fuel use for farming machinery operation and transportation of fuels and grains.

Table 5.4 Total carbon dioxide emissions by dollar asset

Retailer	kg CO_2e / \$ assets
A	0.50
B	0.13
C	0.23
D	0.05
E	0.25
F	0.40
G	---
H	0.10

As mentioned above, the greater the retailer size the greater the emissions. This has an important implication for these firms. If these retailers increase their assets at one location or enlarge their operation, their emissions are likely to get larger, increasing the possibility of being subject to GHGs regulations. Furthermore, since these retailers also function as providers of fuel and agrochemicals for their members, it is possible that if the quantity of fuel they provide is large enough to reach the threshold they can become a covered entity under the current bill. The current bill applies to entities that emits and also deliver materials which use will result in emissions above 25,000 Mt of CO_2e. Emissions associated with the fuels and agrochemicals inputs these retailers supply was not available, but it could be useful to quantify them to better estimate whether these retailers might be covered or not. Whether the final user or the energy producer will be responsible for the emissions depends upon policy design. If these retailers or their energy suppliers become restricted under climate legislation, this may impose an additional cost on them and could also result in higher service prices for their members.

Hence, it is important for these retailers to search for more efficient production systems and renewable sources of energy. Some of these retailers employ alternative sources of energy such as propane and mixes of gasoline and ethanol for their operations and also provide these alternative fuels for their members. This is an important step in addressing GHGs emissions since these alternative fuels have lower associated carbon dioxide emissions rates or are close to carbon neutrality in the case of ethanol. These have resulted in lower carbon emission from energy inputs for these retailers.

5.4 Emissions reduction cost

Once the retailers are aware of their level of emissions, actions could be taken to address areas where emissions can be abated. Actions taken to reduce emissions could result in additional costs for the retailers. To assess the cost of emission reductions, the cost of carbon dioxide emissions was estimated under different reduction levels and carbon prices (Table 5.5 and 5.6). Results of the potential emission reduction costs for two possible carbon prices are displayed in Figure 3.

Under the most pessimistic scenario if retailers were to reduce their total emissions by 20% at a carbon price of \$50 Mt CO_2e^{-1}, then the reduction cost ranges between \$1,347 (for Retailer D) to \$95,877 (for Retailer E). For the rest of the retailers, the cost is in average \$20,000. In contrast, if total emissions were to be reduced by 5% at the same carbon price, costs would be around \$5,000 except for Retailer E and H who have costs of approximately \$24,000 and \$11,000, respectively. For the same scenario, when emission reductions are calculated on direct emissions instead of total emissions, the cost for Retailer E is drastically reduced by approximately 67%. For the rest of the retailers, the change is smaller especially for those retailers who use diesel and gasoline as their main sources of energy. Retailer E shows this pattern because electricity is its main source of energy and as previously discussed, electricity-related emissions are produced off-site and thus are not considered a source of direct emissions for this study. When carbon prices are \$10 Mt CO_2e^{-1}, costs are small under the levels of direct emissions reduction. For a reduction in direct emissions of 20%, costs range from \$209 to \$6,000.

If reductions are calculated using total emissions as a base line, cost could be significantly higher than the reductions when direct emissions are considered as a base line. Direct emissions are those emissions directly related to the use of energy inputs by the retailers and therefore the retailer has more control over them. It is reasonable to think that if a company desires to reduce their emissions by a certain level; they do so by taking their on-site emissions as a base line.

Table 5.5 Emissions reduction cost based on direct emissions

Retailer	Carbon Prices is US$																			
	$10				$15				$20				$30				$50			
	Reduction levels																			
	5%	10%	15%	20%	5%	10%	15%	20%	5%	10%	15%	20%	5%	10%	15%	20%	5%	10%	15%	20%
A	416	833	1,249	1,666	625	1,249	1,874	2,499	833	1,666	2,499	3,332	1,249	2,499	3,748	4,998	2,082	4,165	6,247	8,330
B	259	517	776	1,034	388	776	1,163	1,551	517	1,034	1,551	2,068	776	1,551	2,327	3,102	1,293	2,585	3,878	5,170
C	590	1,181	1,771	2,361	885	1,771	2,656	3,542	1,181	2,361	3,542	4,722	1,771	3,542	5,313	7,084	2,952	5,903	8,855	11,806
D	52	105	157	209	78	157	235	314	105	209	314	418	157	314	471	628	261	523	784	1,046
E	1,552	3,103	4,655	6,207	2,327	4,655	6,982	9,310	3,103	6,207	9,310	12,413	4,655	9,310	13,965	18,620	7,758	15,516	23,274	31,033
F	507	1,013	1,520	2,026	760	1,520	2,279	3,039	1,013	2,026	3,039	4,052	1,520	3,039	4,559	6,078	2,533	5,065	7,598	10,131
G	602	1,203	1,805	2,407	903	1,805	2,708	3,610	1,203	2,407	3,610	4,814	1,805	3,610	5,415	7,221	3,009	6,017	9,026	12,034
H	1,286	2,572	3,858	5,144	1,929	3,858	5,787	7,716	2,572	5,144	7,716	10,288	3,858	7,716	11,574	15,432	6,430	12,860	19,290	25,719

Table 5.6 Emissions reduction cost based on total emissions

Retailer	Carbon Prices is US$																			
	$10				$15				$20				$30				$50			
	Reduction levels																			
	5%	10%	15%	20%	5%	10%	15%	20%	5%	10%	15%	20%	5%	10%	15%	20%	5%	10%	15%	20%
A	1,080	2,159	3,239	4,318	1,619	3,239	4,858	6,477	2,159	4,318	6,477	8,636	3,239	6,477	9,716	12,954	5,398	10,795	16,193	21,590
B	526	1,052	1,577	2,103	789	1,577	2,366	3,155	1,052	2,103	3,155	4,206	1,577	3,155	4,732	6,309	2,629	5,258	7,886	10,515
C	781	1,562	2,343	3,124	1,172	2,343	3,515	4,686	1,562	3,124	4,686	6,248	2,343	4,686	7,029	9,372	3,905	7,810	11,715	15,621
D	67	135	202	269	101	202	303	404	135	269	404	539	202	404	606	808	337	673	1,010	1,347
E	4,794	9,588	14,382	19,175	7,191	14,382	21,572	28,763	9,588	19,175	28,763	38,351	14,382	28,763	43,145	57,526	23,969	47,939	71,908	95,877
F	938	1,877	2,815	3,753	1,408	2,815	4,223	5,630	1,877	3,753	5,630	7,507	2,815	5,630	8,445	11,260	4,692	9,383	14,075	18,767
G	833	1,665	2,498	3,330	1,249	2,498	3,746	4,995	1,665	3,330	4,995	6,660	2,498	4,995	7,493	9,990	4,163	8,325	12,488	16,651
H	2,187	4,374	6,561	8,748	3,280	6,561	9,841	13,122	4,374	8,748	13,122	17,495	6,561	13,122	19,682	26,243	10,935	21,869	32,804	43,739

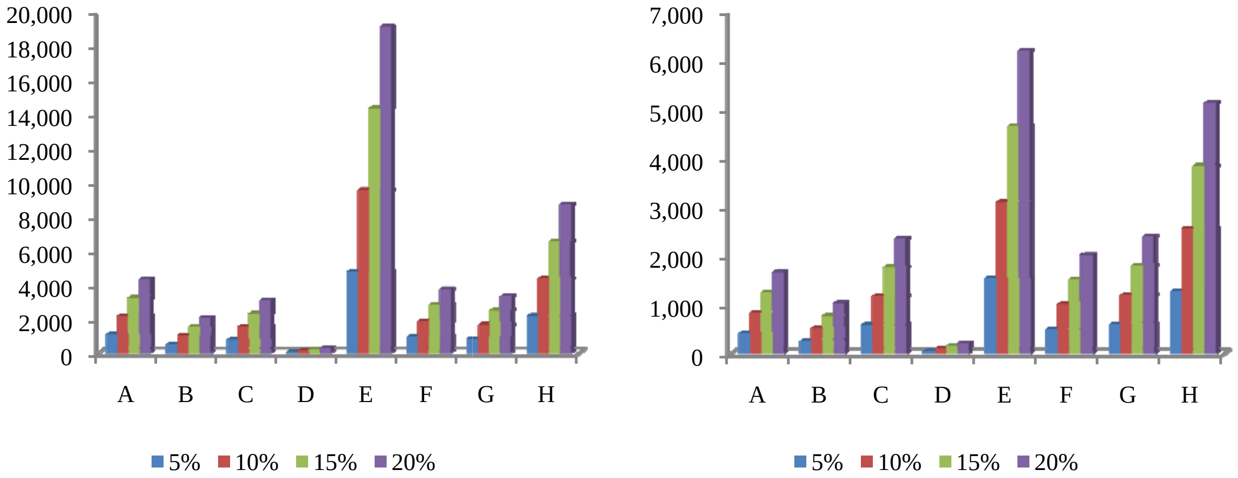
In order to assess the magnitude of the emissions reduction cost, it is important to compare this cost with their current level of operational cost to determine if they represent a significant quantity compared to the operational cost of the retailers. No information to that extent is available.

If these firms purchase carbon credits they could obtain carbon offsets from their member farmers. As previously mentioned, farmers could generate carbon offsets through conservation tillage. Considering the acreage under not-tillage system these retailers serve, it could be possible for their members to generate carbon offsets in a sufficient amount to cover carbon burdens at the retail level. However, these operations are not vertically integrated and thus the members are not obliged to surrender offsets for the emissions at the retail operation. But in the event that agribusiness operations were required to hold carbon offsets it may be possible that the members choose to partially or totally supply the amount set by law.

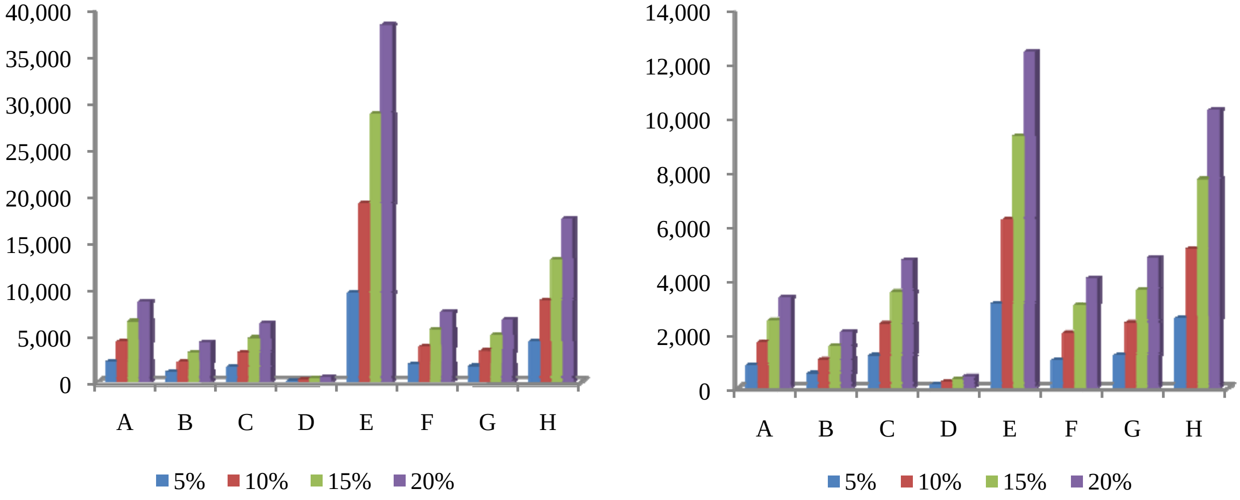
Besides offsetting emissions with carbon offsets from sequestration projects, there exist other alternatives to emissions abatement. These alternatives include increasing the efficiency of energy use and exploring alternative sources of fuels such as renewable sources of energy and bio-fuels. Climate legislation is expected to incentivize companies toward more environmentally sustainable systems of production as the development of new clean technologies takes place and new forms of renewable energy become available. However, these reduction alternatives could also have a cost associated with their implementation.

Figure 3. CO$_2$e emission reduction costs (US$) at different reduction levels

Reduction cost at a carbon price of $10 per metric ton of CO$_2$e



Reduction cost at a carbon price of $20 per metric ton of CO$_2$e



The figures on the left are reductions in total emissions.

The figures on the right are reductions in direct emissions.

Based on the cap and trade bill passed by the House of Representatives, energy end-users (retailers) would not be required to offset their emissions. However, the emissions from producers and providers of several of the energy inputs employed by these retailers would be regulated if this legislation were enacted. Thus, it is very likely that the cost imposed on energy generators and suppliers would be passed onto the energy consumers in the form of higher input prices. As a result, if the input prices increase, farmers could be directly affected through higher input prices and also though higher prices in the services retail agribusinesses provide.

5.5 Summary

This chapter described the results from this study. Electricity was found to be the largest contributor to total carbon dioxide-equivalent emissions from the retail operation and fuel was the second largest contributor. Emissions varied across retailers due to the heterogeneity of their activities. The next chapter presents the conclusions drawn from this study and limitations of these research and suggestions for further research are discussed.

CHAPTER 6 - CONCLUSIONS

This study sheds light on a current topic that has raised concerns over the last several years not only in the scientific community but also in the political environment and society in general. Air pollution originating from the combustion of fossil fuels has been a subject debated in the United States House of Representatives and legislation was passed to mitigate GHG emissions and to increase energy efficiency. A cap and trade program will be established and carbon dioxide emissions will be restricted in the near future if this bill becomes law. Even though agriculture is not covered under the current legislation, primary energy suppliers would likely be constrained.

Consequently, agriculture as an end energy user will most likely be affected indirectly through input price increases. Therefore due to the significance of agricultural retailers in Kansas, it is important to assess how they might be affected by the present climate legislation passed by the U.S. House of Representatives.

Carbon dioxide-equivalent emissions were calculated for the operation of eight agribusiness retailers in Kansas. Electricity was found to be one of the largest sources of total emissions from the operation of the retailer firms. Fuels used for vehicles, farm equipment and transportation of inputs and outputs also represented a significant source of total emissions and the main source of emissions when only direct (on-site) emissions are considered.

None of the eight retailers had locations that could be subject to the current cap and trade bill passed by the House of Representatives. The largest amount by retailer was less than 20,000 tons of CO_2e. The main location of that retail cooperative is similar in size to retailers of a comparable or smaller size. Thus, it is unlikely that local agricultural retailers will be subject to the cap and trade legislation proposed by Congress. In the case that agribusiness retail operations were to be regulated and would have to comply with carbon credits for a certain level of their direct emissions, the incurred cost by the retailers in this study would be low based on estimation of future carbon prices in the literature. If the cost is estimated based on reductions of the total emissions, costs could be high especially for those retailers with high upstream emissions mainly originated from electricity use.

Even though it is not possible that these agribusiness retailers will be subject to a cap and trade policy considering the current amount of carbon emissions they generate, changes could be made in an effort to lessen emissions. Carbon regulation could have an effect on decisions of inputs usage by the firms' operations as well as the allocation of land to different crops by their members.

6.1 Limitations of these research

The retail operations in this study are heterogeneous. They differ in size and in the services they provide. Total emissions vary across firms given the differences in their input mix. For that reason the findings in this study may not apply to other retailers, especially to larger vertically integrated retailers.

6.2 Future research

Future studies can evaluate options for emissions abatement including direct reductions in emissions and utilization of low carbon technologies and renewable fuels by these retailers. Furthermore, studies can be conducted to determine the optimal level of energy inputs for these retailers' operation that can be used to maximize profit by reducing emissions at the same time. Reduction in carbon emissions can be accomplished by augmenting energy efficiency, reducing input levels and using alternative low carbon sources of energy.

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