

Practical Training Report

**Carbon Balance for Corn-Ethanol and
Carbon Balance at Jühnde
Bioenergiedorf (Bio Village).**

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I. Introduction

The latest reports and investigations on the different evaluations of biomass crops and conversion processes focus mainly on the Net Energy Balance. They analyzed the different inputs for the crop production and conversion processes components in terms of energy, for example, MJ per gallon of ethanol. This studies doesn't focus on a very important issues and that is the Net Carbon Balance of the crop production and biomass transformation to a fuel.

For this practical training the main study was the NCB of Corn-Ethanol. This particular crop was selected for the analysis because today the United States, which is the biggest CO₂ producers from fossil fuels⁽¹⁾ and a non Kyoto Protocol member, is looking desperately for new energy fuel resources. And one of the main interest of the US government is the production of Corn-Ethanol⁽²⁾, which in terms of energy efficiency is not as efficient as Sugarcane-Ethanol production⁽³⁾. Now a days the United States uses big subsidies for large ethanol production companies, which process the corn and used a large quantities of coal and natural gas in their processes⁽⁴⁾. The intention of this report is to present an evaluation of the incidence of Carbon emissions through this alternative of Biomass and determine a general view of its NCB impact on the environment.

II. Data Resource & Results for Carbon Balance of Corn-Ethanol

There are two main studies for the NEB of Corn-Ethanol made from well know scientists. One is from Hosein Shapouri, who is from the U.S. Department of Agriculture (USDA), Office of the Chief Economist (OCE) and the other from David Pimentel (Cornell University) & Tad W. Patzek (University of California - Berkeley). Shapouri´s and Pimentel & Patzek´s studies use similar evaluation points and inputs to analyze the NEB, but they differ in the weight of the inputs. Also Pimentel & Patzek include some additional energy used in corn irrigation and secondary energy inputs used in the production of corn, such as farm machinery and equipment and cement, steel, and stainless steel, used in the construction of ethanol plants⁽⁵⁾.

Shapouri gives as a final analysis a positive NEB of Corn-Ethanol. The study results suggest that corn ethanol is energy efficient, as indicated by an energy output/input ratio of 1.67⁽⁵⁾. In the other hand Pimentel & Patzek estimate that Ethanol production using corn grain required 29% more fossil fuel energy than the ethanol fuel produced ⁽³⁾.

Table n°1 shows the farm energy inputs of corn production per hectare of each study. The basic concepts of corn yield per ha and seeds needed per ha are similar and also the Nitrogen input show almost the same values. But the rest of the inputs are different in quantity and also differ in which source they used for them. Fossil fuels like diesel and gasoline shows some similarities. The important idea taken from this two studies is to research in detail additional inputs which are not look up in the majority of the Corn-Ethanol studies, inputs like machinery, lime and labor could play a significant part on this analysis and also we are encourages to look for possible neglected data or circumstances not taken in consideration by prior analysis.

Table n°1. General information from farm inputs used by Shapouri and Pimentel & Patzek.

Analysis		Shapouri 2004		Pimentel & Patzek 2005		Reference	Shapouri 2004	Pimentel & Patzek 2005
Inputs		Unit	weighted	Unit	weighted	Unit	weighted	weighted
Average yield		bushels/acre	139,40	Kg/ha	8.655,00	Kg/ha	8.768,22	8.655,00
Farm inputs	Seed	kernels/acre	28.739,00	Kg/ha	21,00	Kg/ha	24,83	21,00
Farm inputs	Nitrogen (N)	pounds/acre	133,50	Kg/ha	153,00	Kg/ha	149,95	153,00
Farm inputs	Potash (K ₂ O)	pounds/acre	88,20			Kg/ha	99,07	
Farm inputs	Potassium (K)			Kg/ha	77,00	Kg/ha		77,00
Farm inputs	Phosphate (PO ₄)	pounds/acre	56,80			Kg/ha	63,80	
Farm inputs	Phosphorus (P)			Kg/ha	65,00	Kg/ha		65,00
Farm inputs	Lime	pounds/acre	15,70	kg/ha	1.120,00	Kg/ha	17,63	1.120,00
Farm inputs	Diesel	galons/acre	6,90	liters/ha	88,00	liters/ha	64,54	88,00
Farm inputs	Gasoline	galons/acre	3,40	liters/ha	40,00	liters/ha	31,80	40,00
Farm inputs	LPG	galons/acre	3,42			liters/ha	31,99	
Farm inputs	Electricity	kWh/acre	33,60	kWh/ha	13,20	kWh/ha	83,03	13,20
Farm inputs	Natural Gas	cubic ft/acre	246,00			m ³ /ha	17,21	
Farm inputs	Chemicals	pounds/acre	2,66			Kg/ha	2,99	
Farm inputs	Herbicides			Kg/ha	6,20	Kg/ha		6,20
Farm inputs	Insecticides			Kg/ha	2,80	Kg/ha		2,80
Farm inputs	Purch. Water	Dollars/acre	0,20			cm/ha	0,05	
Farm inputs	Irrigation (Water)			cm/ha	8,10	cm/ha		8,10

Because of time constrains this study will analyze in dept the corn production stage of the complete cycle and then will take reference of the wet and dry milling processes CO₂ emissions from different resources.

The farming inputs for the Corn-Ethanol NCB used for this study are shown in table n°2. This inputs will relate at the end with the corn yield per ha. The yield was obtain from the Feed Grains Database: Yearbook Tables from the USDA Economic Research Service (Yields of bushels per acre from 2000-2006). A total yield of 9022,52 corn kg/ha was used for the analysis. This yield is significantly improve over the last decade. This is important to consider in terms of economy and also of sustainability.

Table n°2. List of farming inputs used to determine Net Carbon Balance of Corn-Ethanol.

Item	Input
1	Seeds
2	Labor
3	Machinery
4	Nitrogen (N)
5	Potash (K ₂ O)
6	Phosphate (PO ₄)
7	Sulfur (S)
8	Lime (CaO)
9	Diesel
10	Gasoline
11	LPG
12	Electricity
13	Natural Gas
14	Herbicides
15	Insecticides
16	Irrigation (Water)
17	Transportation

Now lets detail the data resources of this study. Seeds, an average value from Shapouri and Pimentel & Patzek studies was determine.

For Labor input an average of 1,83 hrs./ha was calculated from Characteristics and Production Costs of U.S. Corn Farms, 2001. Linda Foreman⁽⁶⁾.

Table n°3. Equipment needs analysis for Corn-Ethanol production.

Equipment	Weight (tons)	Expected life (years)	Tons/Year	Effective field capacity (Ha/Hrs)	ha/year	Kg/ha
Plows. (Field cultivator)	0,50	9,00	0,06	6,20	250,00	0,20
Tractors	7,00	10,00	0,70	14,00	250,00	2,55
Planters	2,00	3,00	0,67	21,80	250,00	2,43
Harvesters	15,00	12,00	1,25	9,40	250,00	4,55
			2,67			9,72

For the Machinery a basic equipment requirement was taken into account. Farming production depends mainly on plows (field cultivators), planters, tractors and harvesters. The weight in tons of each equipment was taken from shipping weight specifications of the equipment ⁽⁷⁾, then an estimation of the expected life was made

taking into consideration the warranty and reference studies from the Iowa State University⁽⁸⁾. Also is important to mention is that depending on the farming practices some equipment could vary the hectares per year drastically, specially if rotation crops management is practice. The hectares per year by each equipment where estimated from Foreman 2001 ⁽⁶⁾. For this overall estimation mainly an industrial corn farming management is taken into consideration, but with some reserve because equipment with a little more capacity could handle almost as double the hectares ⁽⁶⁾.

Table n°4. Information source of quantities of farming inputs.

Item	Input	Units	Weighted	Adjust Units	Weighted
1	Seeds	22,90	kg/ha	22,90	kg/ha
2	Labor	1,83	hrs/ha	1,83	hrs/ha
3	Machinery	9,72	kg/ha	9,72	kg/ha
4	Nitrogen (N)	132,27	pounds/acre	148,56	kg/ha
5	Potash (KCl)	54,00	pounds/acre	60,65	kg/ha
6	Phosphate (PO4)	46,98	pounds/acre	52,77	kg/ha
7	Sulfur (S)	1,65	pounds/acre	1,85	kg/ha
8	Lime (CaO)	1.000,00	pounds/acre	1.123,19	kg/ha
9	Diesel	17,05	galons/ha	17,05	galons/ha
10	Gasoline	8,40	galons/ha	8,40	galons/ha
11	LPG	8,45	galons/ha	8,45	galons/ha
12	Electricity	83,03	kWh/ha	83,03	kWh/ha
13	Natural Gas	607,87	cubic ft/ha	607,87	cubic ft/ha
14	Herbicides	2,31	kg/ha	2,31	kg/ha
15	Insecticides	0,07	kg/ha	0,07	kg/ha
16	Irrigation (Water)	8,10	cm/ha	8,10	kg/ha
17	Transportation	82,77	MJ/ha	2,30	kWh/ha

According to EPA, nutrient pollution is the leading cause of water quality impairment in lakes and estuaries and the third leading cause in rivers. At high concentrations in the ground water, nitrates make drinking water unsafe. Nitrogen is a very important input for corn production. Nitrogen is essential for plant growth, but every year

when the fields are harvested the nitrogen is removed so farmers need large quantities for the next crops. If Nitrogen is in a highly soluble nitrate form it is leached or eroded from fields and can pollute ground or surface water ⁽⁹⁾. Also an important comment in regards Nitrogen is that high carbon content soils absorb more Nitrogen, so from the applied Nitrogen a percentage won't be used directly by the plant. From the USDA (2006), Agricultural Chemical Usage 2005 Field Crops Summary we used the quantity values for Nitrogen, Potash, Phosphate and Sulfur ⁽¹⁰⁾.

Potash is important for agriculture in general because it increases root growth, improves drought resistance, helps retard crop diseases, maintains cell turgor, reduces water loss and wilting, increases protein content of plants, aids in photosynthesis, regulates production of high energy plant growth compounds, activates more than 60 enzyme systems, produces grain rich in starch, builds cellulose and reduces lodging due to weak stalks ⁽¹¹⁾.

Phosphate is very important for corn production but it has some side effects, surface runoff of phosphates from excessively fertilized farmland can be a cause of phosphate pollution leading to eutrophication (nutrient enrichment), algal bloom and consequent oxygen deficit. This can lead to anoxia for fish and other aquatic organisms in the same manner as phosphate-based detergents ⁽¹²⁾.

Lime is a soil additive made from pulverized limestone or chalk. Its primary active component is calcium carbonate. Additional chemicals vary depending on the mineral source and may include calcium oxide, magnesium oxide and magnesium carbonate. It has many effects on soil: it increases the pH of acidic soils, it provides a source of calcium for plants, it permits improved water penetration for acidic soils. Lime may occur naturally in some soils but may require addition of sulfuric acid for its

agricultural benefits to be realized. Gypsum is also used to supply calcium for plant nutrition but will not raise the soil's pH ⁽¹²⁾.

The values used in the NEB mentioned studies differ greatly, so information from the Farm business Management Guide (University of Missouri) Corn Silage Budget Melvin Brees and Brent Carpenter 2006 was used ⁽¹³⁾. This values are congruent with Pimentel & Patzek study.

Diesel, Gasoline, LPG, Electricity and Natural gas values for the NCB analysis are from Shapouri which got this inputs from 2001 Agricultural Resource Management Survey (ARMS), which are available at the Economic Research Service from the USDA ⁽¹⁴⁾.

Herbicides and Insecticides inputs of 2,31 kg/ha and 0,71 kg/ha respectively are used ⁽¹⁰⁾.

To Analyze Irrigation of corn crops the following assumptions where made, with reference to Patzek 2006 Thermodynamics of the Corn-Ethanol Biofuel Cycle. Only 15% of the corn crops are irrigated, an average 8.1 cm of water is used per acre, Water is pumped on average from the depth of 100 m and Pump efficiency of about 85% ⁽¹⁵⁾.

Transportation of goods, seeds, equipment and machinery was estimated in 2,30 kWh/ha from Wang ⁽¹⁵⁾.

All this inputs where adjusted to input weight per hectare.

Many scientist, politicians and farming organization promote the use of biofuels as a reliable source of alternative and clean energy. And many studies present positive NEB for this production of biofuel, despite of many environmental implications like pollution from agrochemicals and from some nutrients and also the fact that if is not done in a well manage process it can put in risk the production of food for humans

and also for animal feeding. Table n°5 details the different weights of Carbon emissions from the inputs analyze in this report.

Table n°5. Carbon emissions from Corn production inputs.

Item	Input	Units	Weighted	Observations
1	Seeds	2,01	kg/ha	Carbon emissions from manufacture
2	Labor	4,79	kg/ha	Carbon emissions from manufacture
3	Machinery	1,47	kg/ha	Carbon emissions from manufacture
4	Nitrogen (N)	93,70	kg/ha	Carbon emissions from manufacture
5	Potash (KCl)	0,99	kg/ha	Carbon emissions from manufacture
6	Phosphate (PO4)	7,56	kg/ha	Carbon emissions from manufacture
7	Sulfur (S)	1,17	kg/ha	Carbon emissions from manufacture
8	Lime (CaO)	240,47	kg/ha	Carbon emissions from manufacture
9	Diesel	46,92	kg/ha	This are carbon emissions to the atmosphere
10	Gasoline	20,21	kg/ha	This are carbon emissions to the atmosphere
11	LPG	13,41	kg/ha	This are carbon emissions to the atmosphere
12	Electricity	13,89	kg/ha	This are carbon emissions to the atmosphere
13	Natural Gas	29,45	kg/ha	This are carbon emissions to the atmosphere
14	Herbicides	0,33	kg/ha	Carbon emissions from manufacture
15	Insecticides	0,01	kg/ha	This are carbon emissions to the atmosphere
16	Irrigation (Water)	53,59	kg/ha	Carbon emissions from manufacture
17	Transportation	0,39	kg/ha	This are carbon emissions to the atmosphere
		530,35	kg/ha	

The Carbon emission weight per input depends on a wide spread of data and in dept analysis which lead to the final Carbon emissions from the production of Corn crops. To calculate the CO2 emissions from a gallon of fuel, the carbon emissions are multiplied by the ratio of the molecular weight of CO2 (m.w. 44) to the molecular weight of carbon (m.w.12): 44/12. Now an example, CO2 emissions from a gallon of

gasoline = 2,421 grams x 0.99 x (44/12) = 8,788 grams = 8.8 kg/gallon = 19.4 pounds/gallon.

For the Seeds the following analysis was made: If all the other inputs add to 528,33 Carbon Kg/ha to yield 9022,52 Kg of corn per ha, then 22,9 kg of corn seeds multiply by de Carbon emissions and divided by the yield will give the Carbon Kg/ha. An additional 50% emissions was added because of additional drying and packing that is needed for the Seeds final process.

Labor, this item has an interesting situation, Worldwide the average Carbon Kg/per capita is 4,780 but for the United States alone is 22,924 Kg/ per capita ⁽¹⁶⁾, eventhough labor is not a big input for corn production it can be a delicate issue on more labor intensive Biomass or Renewable Energy production for the USA.

For the Machinery no specific manufacture emission data was found, so a reference from the German steel production company Stahl was used, about 2439 Kg of CO₂ per ton of steel ⁽¹⁷⁾.

Nitrogen as said before is one of the most important inputs in Corn production, an average between Patzek analysis and the company Potash Corp, which specialicies in the production of fertilizers. Patzek ⁽¹⁵⁾ provides 2,7 Kg of CO₂ / Kg of Nitrogen and Potash Corp. ⁽¹⁸⁾ 1,925 Kg of CO₂ / Kg of Nitrogen which leaves us with 2,3 Kg of CO₂ / Kg of Nitrogen.

Potash and Phosphate values are also from Potash Corp. ⁽¹⁸⁾. For Sulfure, because is a such a small size input and no specific emission reference was found the CO₂

kg/Kg of Nitrogen production was used as reference. Lime, values are of 0,785 Kg of CO₂ / Kg of Lime from Energy Information Administration ⁽²⁰⁾.

Diesel and Gasoline, which are direct fossil fuels use in the corn production input weights of 46,92 and 20,21 Kg of Carbon, respectively, per hectare of Corn ⁽²⁰⁾.

From the Energy Information Administration CO₂ Kg per unit of LPG, Electricity and Natural Gas where establish at 12,805 pounds of CO₂ per LPG gallon, 1,350 pounds of CO₂ per Kwh of Electricity and 1,314 pounds of CO₂ / kwh for Natural Gas ⁽¹⁹⁾.

For the Herbicides and Insecticides a value of ,525 Kg of CO₂ per Kg is used. This reference value comes from the Phosphate values because the energy use per Kg of Herbicides and Insecticides production is close to Phosphate and a close relationship between the energetic intensity of the inputs manufacture and the CO₂ emissions is visible ⁽¹⁵⁾.

Irrigation energy needs where determine by calculations to 395,3 kwh per 1000 m³ of water ⁽²¹⁾. To perform this calculations a small software from Wateright was used and also reference information from Pimentel & Patzek report ⁽³⁾.

Transportation, the MJ/ha where transform into Kwh/ha and then use the 1,350 pounds of CO₂ per kwh from the Electricity analysis.

All this analysis reaches the final value of 530,35 Kg of C per hectare of produce Corn.

The Ethanol production can be done through two different process, Dry or Wet Milling. For this analysis an average from the Dry and Wet Milling NEB of Shaupuri

and Pimentel & Patzek is used to then calculate the Carbon emissions from this processes. How this two process work is detail from the Renewable Fuel Association (22). In dry milling, the entire corn kernel or other starchy grain is first ground into flour, which is referred to in the industry as "meal" and processed without separating out the various component parts of the grain. The meal is slurried with water to form a "mash." Enzymes are added to the mash to convert the starch to dextrose, a simple sugar. Ammonia is added for pH control and as a nutrient to the yeast. The mash is processed in a high-temperature cooker to reduce bacteria levels ahead of fermentation. The mash is cooled and transferred to fermenters where yeast is added and the conversion of sugar to ethanol and carbon dioxide (CO₂) begins. The fermentation process generally takes about 40 to 50 hours. During this part of the process, the mash is agitated and kept cool to facilitate the activity of the yeast. After fermentation, the resulting "beer" is transferred to distillation columns where the ethanol is separated from the remaining "stillage." The ethanol is concentrated to 190 proof using conventional distillation and then is dehydrated to approximately 200 proof in a molecular sieve system. The anhydrous ethanol is then blended with about 5% denaturant (such as natural gasoline) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers. The stillage is sent through a centrifuge that separates the coarse grain from the solubles. The solubles are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are then dried together to produce dried distillers grains with solubles (DDGS), a high quality, nutritious livestock feed. The CO₂ released during fermentation is

captured and sold for use in carbonating soft drinks and beverages and the manufacture of dry ice.

In wet milling, the grain is soaked or "steeped" in water and dilute sulfurous acid for 24 to 48 hours. This steeping facilitates the separation of the grain into its many component parts.

After steeping, the corn slurry is processed through a series of grinders to separate the corn germ. The corn oil from the germ is either extracted on-site or sold to crushers who extract the corn oil. The remaining fiber, gluten and starch components are further segregated using centrifugal, screen and hydroclonic separators. The steeping liquor is concentrated in an evaporator. This concentrated product, heavy steep water, is co-dried with the fiber component and is then sold as corn gluten feed to the livestock industry. Heavy steep water is also sold by itself as a feed ingredient and is used as a component in Ice Ban, an environmentally friendly alternative to salt for removing ice from roads. The gluten component (protein) is filtered and dried to produce the corn gluten meal co-product. This product is highly sought after as a feed ingredient in poultry broiler operations.

The starch and any remaining water from the mash can then be processed in one of three ways: fermented into ethanol, dried and sold as dried or modified corn starch, or processed into corn syrup. The fermentation process for ethanol is very similar to the dry mill process described above.

As seen before Dry mills are usually smaller than wet mills and are built primarily to produce ethanol. Wet mills are bio-refineries and produce a wide range of products, not only Ethanol. Both systems use thermal and electrical powers as their main

sources of energy. Wet mills usually generate both electrical and thermal energy from burning natural gas or coal. Dry mills use natural gas to produce steam and purchase electricity from a utility⁽⁵⁾.

Table n°6. Carbon emissions from Ethanol production by ha.

	Shapouri		Pimentel
	Dry (BTU/Bushel)	Wet (BTU/Bushel)	(MJ/L)
Ethanol production	47.116,00	52.349,00	14,50
Transportation	1.487,00	1.487,00	1,90
Total	48.603,00	53.836,00	16,40
Shapouri Average	51.219,50		
Kwh/ha	5.320,44		15.278,14
Total Kwh/ha Average	10.299,29		

Ethanol Production	
Items	C kg/ha
Shapouri	890,40
Pimentel	2.556,88
Average	1.723,64

Table n°6 show our calculations of the average Kg Carbon Emissions per hectare from the Shapouri⁽⁵⁾ and Pimentel⁽³⁾ calculations. Pimentel takes in consideration a big amount of energy from the construction of the ethanol plants and also is Pimentel considers a higher input of transportation in the complete process, almost 13% of the total energy is from transportation. Then the amount of 1.723,64 C Kg/ha is used as reference for the production of Ethanol and transportation to filling stations.

The final result of 2.253,99 Kg of Carbon Emissions / hectare, on the next part of this report different analysis will take place to see in a more clear way the sustainability level of these biofuel production.

III. Evaluation & Analysis of Carbon Balance of Corn-Ethanol

Carbon Credits and Soil Sequestration.

Corn Ethanol is produce from the starch of the corn. Starch is a complex carbohydrate soluble in water and is used by plants to store glucose. Starch accounts for 66% of the total weight of corn kernels⁽⁵⁾. Then from the total Carbon emissions from the Ethanol production a credit of 586,04 C Kg/ha can be apply. Since the 34% of the emissions will correspond to other by products. Also during the growing of the crops some soil sequestration is produce, about 0,2 tonne/ha/year which also can be translate into credits of 181,82 C Kg/ha.

By the process of photosynthesis plants capture carbon and then return some amount to the atmosphere through respiration. Then the carbon that is store in plants can be consumed by animals or added to the soil when plants decompose. This material called Soil Organic Matter⁽²³⁾.

Farmers have different tillage systems and depending on the system use different carbon and nutrient sequestration can be achieve. Depending on the amount of crop residue remaining on the soil from the last crop the Tillage systems are determine. By leaving less than 30 percent of the previous crop residue covering the soil when corn is planted a Conventional tillage is perform. Reduced tillage leaves between 15 percent and 30 percent of the previous crop residue covering the soil and Conservation tillage leaves 30 percent or more of the previous crop residue covering the soil. No-till means that no tillage operations are perform prior to planting⁽⁶⁾. These last two procedures generally reduce soil erosion, improve water use efficiency, and increase carbon concentrations in the topsoil.

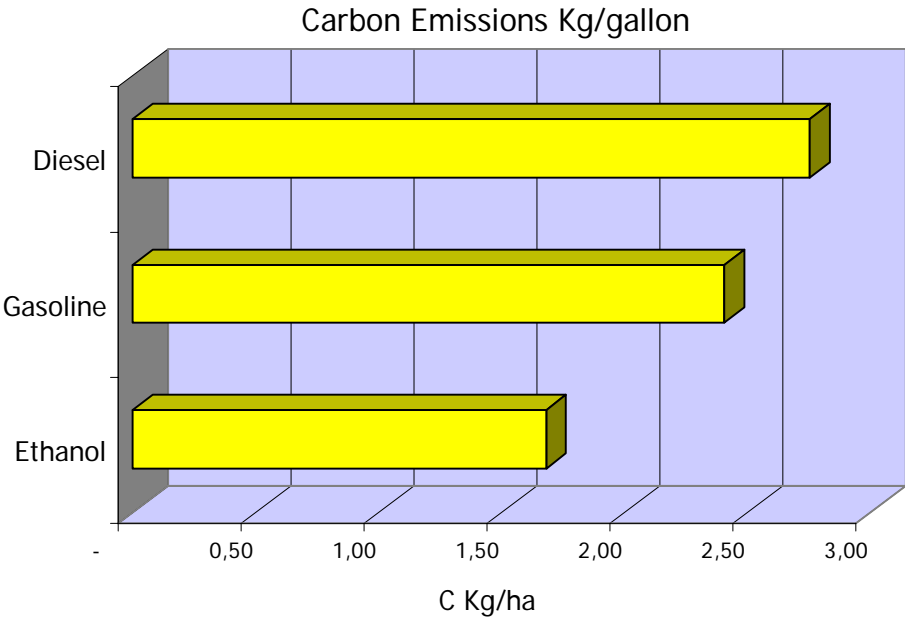
Another agriculture management system is Crop rotation which avoids a decrease in soil fertility, because by growing the same crop repeatedly in the same place will

depletes the soil of various nutrients. A crop that leaches the soil of one kind of nutrient is followed during the next growing season by a dissimilar crop that returns that nutrient to the soil or draws a different ratio of nutrients, for example, rice followed by cottons. By crop rotation farmers can keep their fields under continuous production, without the need to let them lie fallow, and reducing the need for artificial fertilizers, both of which can increase the Carbon emission contribution to the atmosphere.

Legumes have nodules on their roots which contain nitrogen-fixing bacteria. Then it is good practice to alternate them with cereals which require nitrates. A common modern crop rotation is alternating soybeans and corn, this will reduce the Carbon emissions from manufacture nitrogen apply to the field. (12).

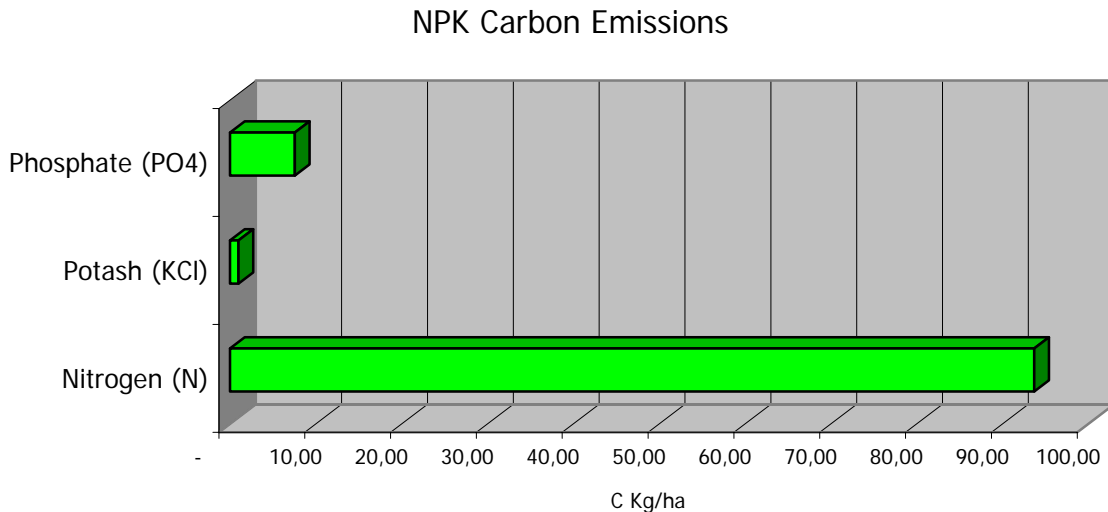
Then our initial total of 2.253,99 Kg of Carbon Emissions / hectare will be reduce to 1.486,13 Kg of Carbon Emissions / hectare. Ethanol yields 886,6 gallons of one hectare of corn then our Ethanol Carbon Emissions per gallon is 1,68.

Graph n°1. Carbon emissions from Ethanol, Diesel and Gasoline per Gallon.



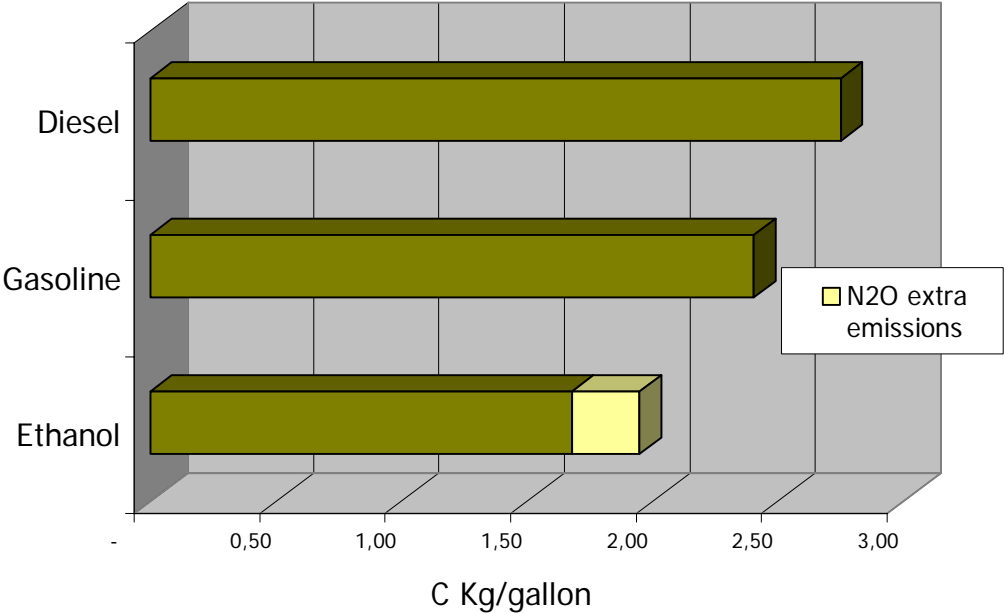
N,P & K Carbon Emissions.

Graph n°2. Carbon emissions from NPK.



From the fertilizer used in Corn production Nitrogen is the most environmental hazardous, not only because of the Carbon emissions from manufacture but also because of the water contamination it produces. Another aspect about Nitrogen is that 1,25% of it escapes into the air as N_2O , also 2,5% of the 30% of Nitrogen apply in the fields is converted into N_2O in surface water and 10% of the applied Nitrogen escapes as NH_3 into the atmosphere and 1% turns into N_2O . Nitrous Oxide is 296 times more potent than CO_2 . This means that from Nitrogen application to Corn fields an extra 3 Kg of Nitrogen per hectare (calculations made from table n°4) go to the atmosphere, then an additional 242,2 Kg C per hectare will increase the total Carbon emissions from Corn production to 1.728,33 Kg C/ha in consequence 1,95 Kg C/gallon of Ethanol (Graph n°3).

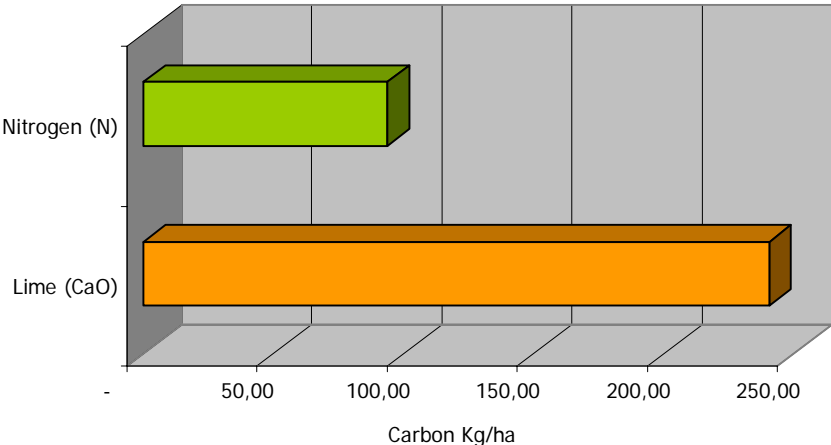
Graph n°3. Carbon emissions from Ethanol, Diesel and Gasoline per Gallon with extra N₂O emissions in Ethanol.



Lime Carbon Emissions.

As mention before Lime plays an important part on plant grow, it helps plant efficiency on water absorption, but is needed in large quantities.

Graph n°4. Carbon Emissions from Lime.

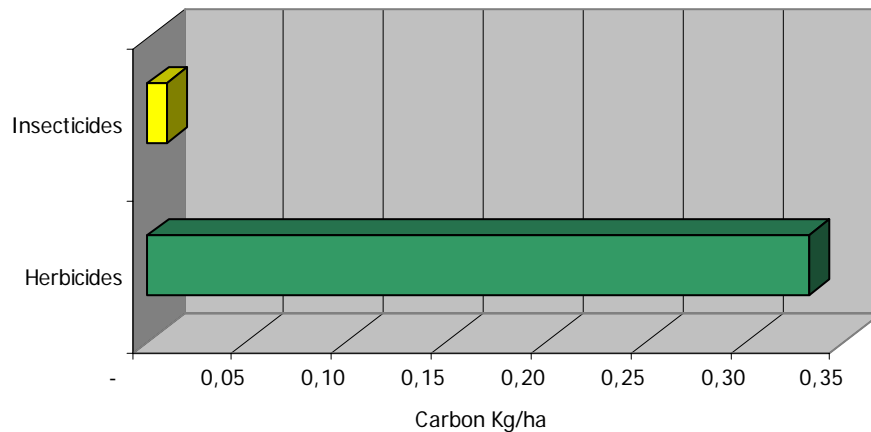


Even though Nitrogen production emits more than 3 times Carbon emissions, lime weight input per hectare is almost 8 times larger than Nitrogen. According to the

Farm business Management Guide (University of Missouri) this need for Lime is present in almost all the Corn production industry.

Herbicides & Insecticides.

Graph n°4. Carbon Emissions from Herbicides & Insecticides.



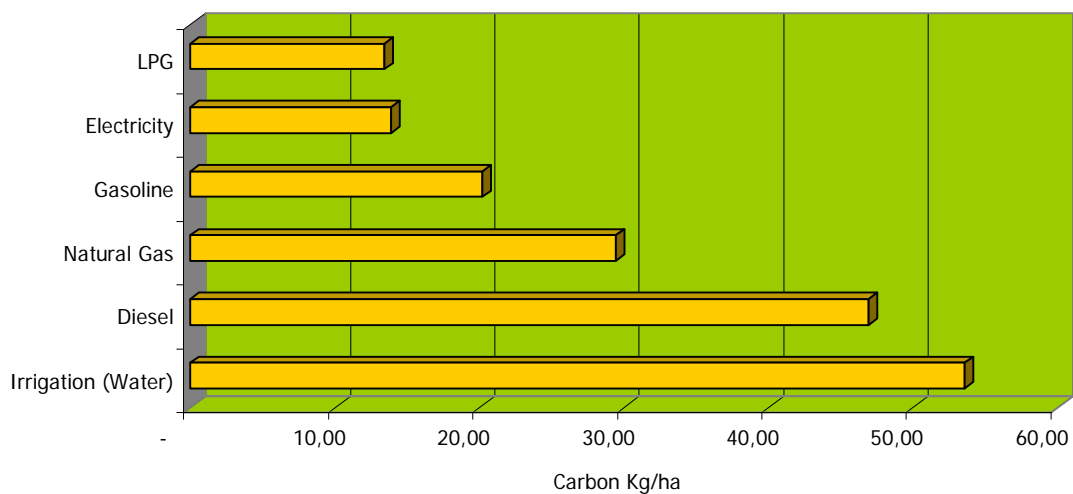
Herbicides and Insecticides don't play a significant effect on the Carbon emissions, but nevertheless there is profound evidence that continues to highlight the danger of foods and vegetables made with the help of insecticides, many studies have documented the negative health effects these chemicals have on farmers who grow most of the foods sold to the general public. Some of this investigation found that farmers who used agricultural insecticides experienced increased neurological symptoms, even after they stopped using the products. This neurological problems include headaches, fatigue, insomnia, dizziness, nausea, hand tremor and numbness⁽²⁵⁾.

Electricity, Diesel, Gasoline, LPG & Water Irrigation.

This inputs are the more direct source of Carbon emissions on field and after Lime the biggest contributors to Carbon emissions. This are greatly related to the Machinery used on the farming process.

Because of the characteristics of the soil and of the Corn crops Water Irrigation presents an important issue on Crop grow but since most of the water comes from wells it needs pumping systems, sometimes that goes 100m under ground which demands fossil fuels to perform.

Graph n°5. Carbon Emissions from LPG, Electricity, Gasoline, Natural Gas, Diesel and Water Irrigation.

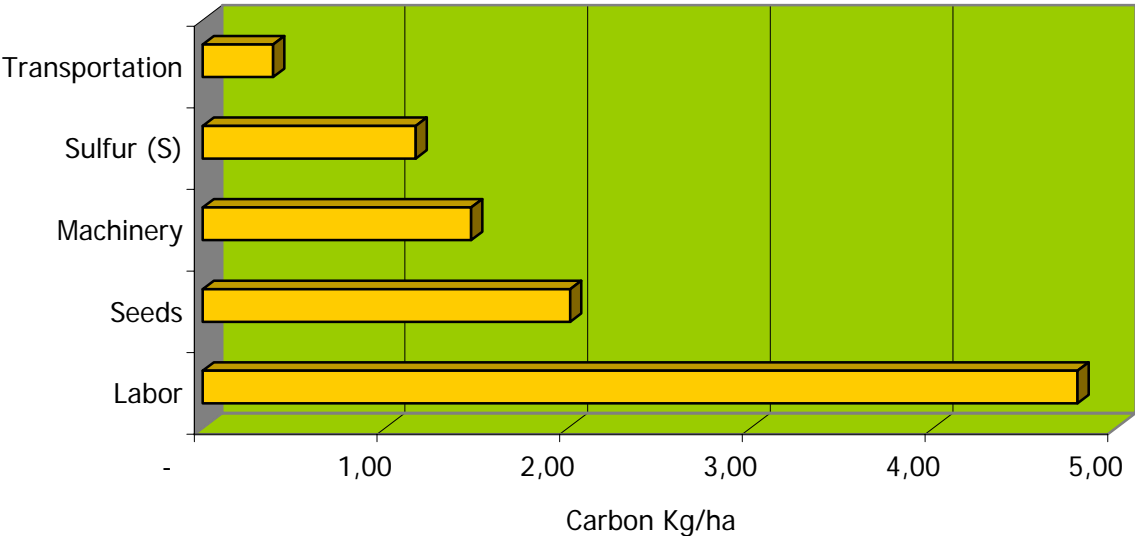


Seeds, Labor, Machinery, Transportation & Sulfure.

Even though this inputs don't give an important weight factor in the production of Corn, is important to consider them, because for example depending on for which country this analysis is perform Labor can change drastically its input and also Machinery and Transportation. The first one because industrialized countries

normally have a higher Carbon Emission per Capita and developing countries may incur in higher Machinery and Transportation Emissions because of different technologies and also because of the larger distances to transport equipment and inputs.

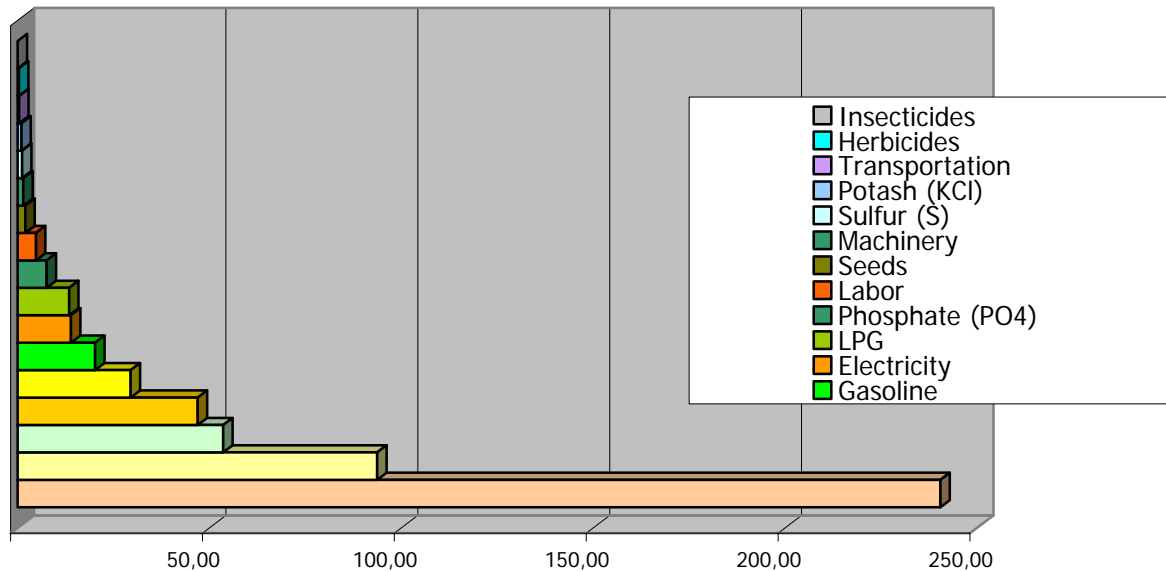
Graph n°6. Carbon Emissions from Transportation, Sulfure, Machinery, Seeds and Labor.



Total Carbon Emissions from farming inputs & NCB for Corn-Ethanol.

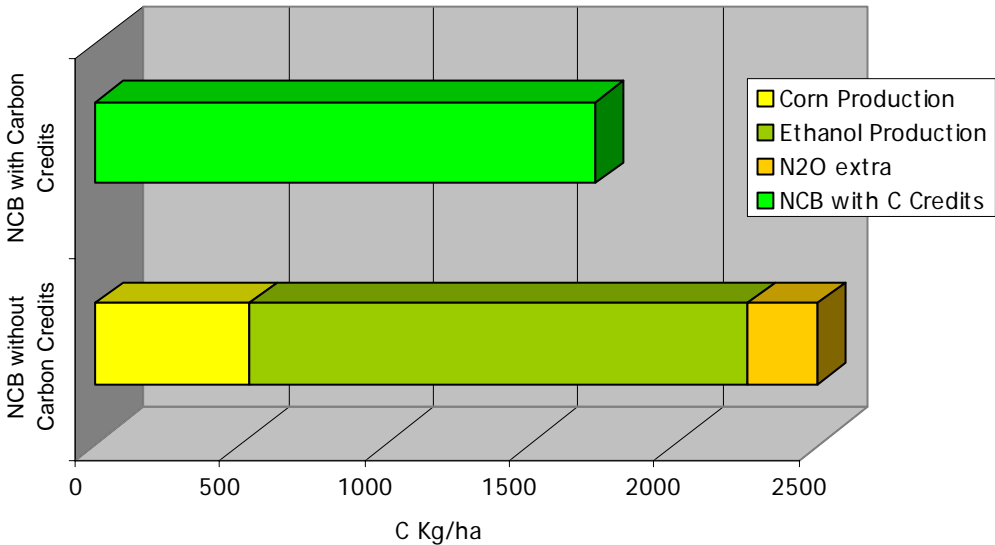
After finishing the NCB for Corn-Ethanol at a production yield of 886,06 gallons of Ethanol per hectare with a total Carbon emission of 1.728,33 Kg C/ha which means 1,95 Kg C/gallon of Ethanol is visible on Graph n°7 and n°8. Improvements on specific areas like use of more effective systems for providing Nitrogen and Lime to the crops must be analyze as well as improvements on Ethanol production facilities, Wet or Dry, which consume large quantities of fossil fuels should be look up.

Graph n°7. Total Carbon Emissions from farming inputs per hectare.



The Nitrogen issue can be address with better farming management, like changing the tilling systems and the use of crop rotation so the soil is not depleted from important nutrients.

Graph n°8. NCB for Corn-Ethanol



A really important issue which is determine by the final user, referring to the engine which is run with Ethanol, is the Fuel Economy. To do this analysis LHV of Ethanol, Gasoline and Diesel are used, which are 19,05, 29,56 & 31,95 MJ/L respectively (12).

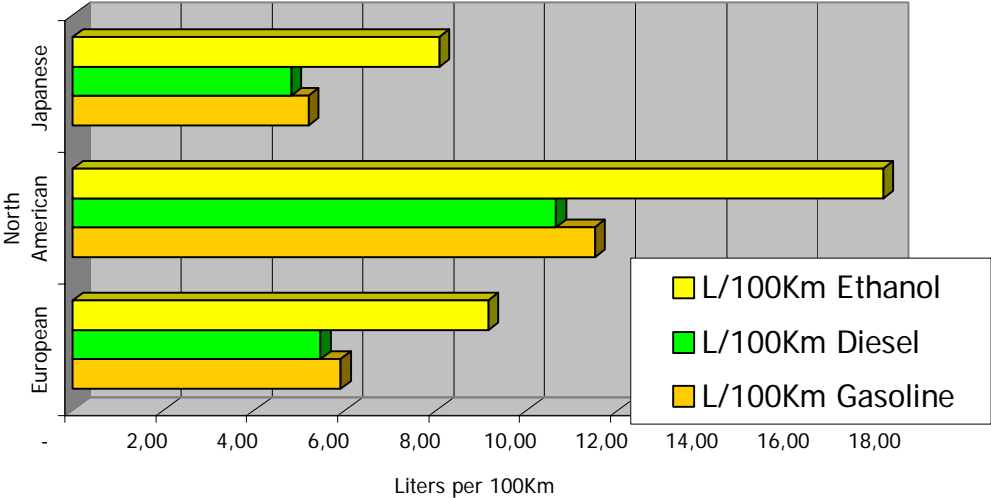
Table n°7. Carbon emissions Analysis for Liters per 100 Km.

Fuel	LHV (MJ/L)	Normalize LHV
Ethanol	19,05	0,64
Gasoline	29,56	1,00
Diesel	31,95	1,08

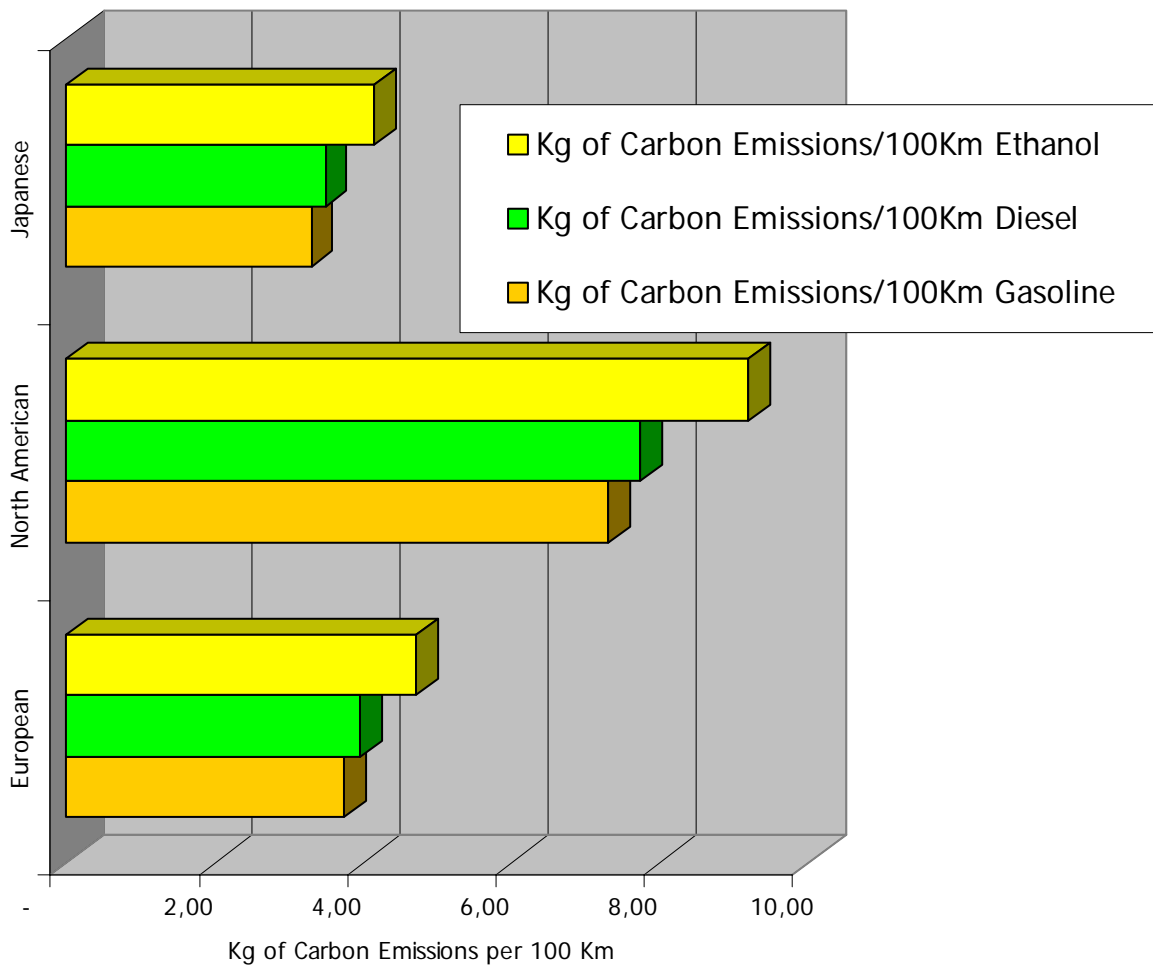
Type of Car	L/100Km		
	Gasoline	Diesel	Ethanol
European	5,90	5,46	9,15
North American	11,50	10,64	17,84
Japanese	5,20	4,81	8,07

Type of Car	Kg of Carbon Emissions/100Km		
	Gasoline	Diesel	Ethanol
European	3,75	3,97	4,71
North American	7,31	7,73	9,19
Japanese	3,30	3,50	4,16

Graph n°9. Fuel Economy. Litters per 100 Km.



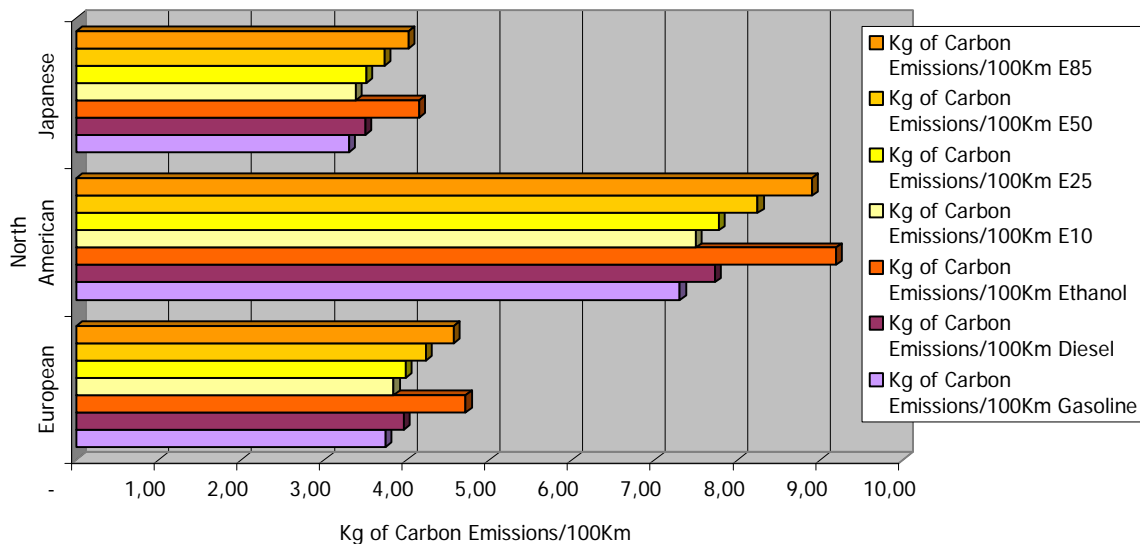
Graph n°10. Fuel Economy relationship to Carbon Emissions.



Using Gasoline as reference it means that an Ethanol car engine requires 1,56 more Ethanol to achieve the same LHV and a Diesel car engine will use 0,08 less Diesel in proportion to Gasoline, all this in terms of L/100 Km. From table group n°7 can be seen that the Kg of Carbon Emissions per 100 Km run in different types of standard vehicles is not so favorable to Ethanol, mainly because of its Low LHV in comparison with Gasoline and Diesel. But even if those figures are adjusted to an E10 mix the Kg of Carbon Emissions per 100 Km on the European, North American and Japanese vehicles will be slightly higher 3,85, 7,49 and 3,39 C Kg/ 100 Km respectively. Graph n°11 show that only E10 and E25 blends will be under the emissions produce by

Diesel and as the Ethanol content is increase the Carbon Emissions per 100Km get higher than Diesel and Gasoline.

Graph n°11. Fuel Economy relationship to Carbon Emissions of Different Ethanol Gasoline Blends.



Recently a study from Stanford University atmospheric scientist Mark Z. Jacobson, states that if every vehicle in the United States uses fuels mainly from ethanol the number of respiratory-related deaths and hospitalizations would be likely to increase.

This study details that even though carcinogens, from gasoline emissions, like benzene and butadiene are reduce, Ethanol fuels produce two others, formaldehyde and acetaldehyde, and that also increases ozone levels, which can decrease lung capacity, inflame lung tissue, worsen asthma and impair the body's immune system, according to the Environmental Protection Agency. And this situation is regardless of the biomass used, corn, switchgrass or other biomass sources⁽²⁶⁾.

Perhaps is time to take a deep look at Ethanol production and perform more detail analysis so we can completely benefit from this fuel source, which is an alternative to fossil fuels but as seen in this reports with some limitations. But in the other side is

able to reduce the dependence on fossil fuels specially for non producer countries and bring socioeconomical benefits to rural areas of this countries. It is recommended that the use of this alternative should be some how regulated but in terms of an international level because issues like food displacement by fuel needs and fuel efficiencies must be taken into account so that the final impact of the Ethanol is in overall a real benefit to this Planet that we all live in and expect our future generations to have a better environmental situation than the one we have.

IV . Jühnde Bioenergiedorf

Jühnde is a small German village in Lower Saxony between Göttingen and Kassel. Approximately 700 persons live in Jühnde. This village is the first German village to produce heat and electricity by means of renewable energy from Biomass. Through this energetic system a CO₂ Neutral Balance is achieved. Jühnde was chosen over other villages because it fulfills 4 requirements: Farmer community, available land, Forest in the surrounding areas and over 60% of commitment of the villagers.

From the information obtained by visiting the Jühnde Bioenergiedorf (Biovillage) the system is detailed:

The Bioenergy Plant is formed by three main components:

- Anaerobic digestion plant with a block type thermal power station.
- Wood chip burning boiler.
- Village heating grid.

Anaerobic digestion plant with a block type thermal power station.

The Anaerobic digester uses silage and liquid manure (400 Cows and 1000 pigs) from the farmers at Jühnde. This supply of silage and manure is made by contract to secure the feedstock of 300 hectares for the silage input to the digester, from the farmers of Jühnde. Around 12.000 tons of silage and 10.000 m³ liquid manure are first fermented in a four step process which produce biogas. The silage is composed by wheat, rye, triticale, corn, sunflowers, grass. The Fermenter has a 3000 m³ capacity. The biogas, which is stored in a 5.200 m³ tank, is used in the block type thermal power station to produce electricity and heat. The block type thermal power station has a capacity of 700 kW. The electricity is sold to the grid and the heat from generation is used for the village heating system.

The initial design estimation establish a 4.000.000 kwh of electricity generation per year, but they have achieve 4.500.00 kwh. Also they produce approximately 3.000.000 kwh of heat, which represents 67% of the annual heat demand of the Village.

Is important to mention that even though farmers use slurry as a fertilizer they have just decrease the use of fertilizer by approximately 25%. In the case of Herbicides and Insecticide use a reduction of approximately 1/3 has been establish mainly for the crops use for the biomass process since the quality requierements are not that high.

Wood chip burning boiler.

Since the complete demand in winter is over 3.000.00 kwh of heat a complementary system of Wood chip burning boiler contributes to complete this demand. This system is compose by a combustion oven which dried the wood chips in several steps until the final burnt.

The 550 KW oven needs around 600 cords of wood, which are purchase from local suppliers, but the original idea was to retrieve this from the surrounding forests. The heat production is of 1.200.000 kwh per year, but this production is only during the months of October to April to complete the 33% missing from the CHP.

In the case of extreme heat demands or the complete break down of the whole plant an additional boiler can provide the heat for the village. This 1,6 MW boiler unit runs on oil, this extreme winter heat demand corresponds only to 5% of the annual demand.

During the rest of the year, when no heating is demanded, the plant produces extra heat. This extra heat will be use in a near future to provide drying services for

farmers, so an extra profit can be achieved from this both in the economical and carbon emission side.

Jühnde heating grid.

Around 75% of the village is connected to a new heating grid, this amounts to over 150 houses. This grid of about 6.000 m of pipes provides a water temperature of 80°C at a maximum pressure of 4,5 bar.

As mentioned before the commitment to the project from the villagers is a very important part to make the Jühnde Energiedorf a success, this commitment is present by acquiring the heating services from the plant and not from external sources.

They claim to produce a negative 3.300 tons of CO₂ emission per year when the system is completely active.

In terms of revenue this project provides the following benefits its first year of running:

Heating savings from €200.000,00 to €300.000,00.

Gross income per year :	€800.000,00
Running cost:	€150.000,00
Interest and administrative cost:	€160.000,00
Silage and wood cost:	€350.000,00

Since the silage is provided from Jühnde's farmers the complete benefits to the community are around €400,000.00 per year. This cooperative system run plant had a total cost around €5,3 Millions.

Jühnde is an example of how a well organized community can achieve important goals to help directly the environment. Biomass has many advantages and in organized management processes it can give a better overall performance because it

represents economical, social and environmental gains. The total NCB for Jühnde should will be an interesting project to maybe in a near future complement the Corn-Ethanol study since this is a more control system and probably will produce negative Carbon emissions even though we take more strict considerations for the production of silage and biogas production.

V. Conclusions

1. Corn-Ethanol production is not as efficient as Sugarcane-Ethanol production.
2. A total yield of 9022,52 corn kg/ha was used for the analysis. This yield is significantly improve over the last decade.
3. Nutrient pollution is the leading cause of water quality impairment in lakes and estuaries and the third leading cause in rivers. At high concentrations in the ground water, nitrates make drinking water unsafe.
4. Nitrogen is a very important input for corn production. Nitrogen is essential for plant growth.
5. To calculate the CO₂ emissions from a gallon of fuel, the carbon emissions are multiplied by the ratio of the molecular weight of CO₂ (m.w. 44) to the molecular weight of carbon (m.w.12): 44/12.
6. Worldwide the average Carbon Kg/per capita is 4,780 but for the United States alone is 22,924 Kg/ per capita.
7. Conservation tillage and No-till generally reduce soil erosion, improve water use efficiency, and increase carbon concentrations in the topsoil.
8. Crop rotation farmers can keep their fields under continuous production, without the need to let them lie fallow, and reducing the need for artificial fertilizers, both of which can increase the Carbon emission contribution to the atmosphere.
9. Nitrogen application to Corn fields add an extra 3 Kg of Nitrogen per hectare which go to the atmosphere, which means an additional 242,2 Kg C per hectare will increase the total Carbon emissions from Corn production to 1.728,33 Kg C/ha which convert to 1,95 Kg C/gallon of Ethanol, before Carbon credits.

10. Nitrogen production emits more than 3 times Carbon emissions, lime weight input per hectare is almost 8 times larger than Nitrogen.
11. Many studies have documented the negative health effects of the use of herbicides and insecticides have on farmers who grow most of the foods sold to the general public. Some of this investigation found that farmers who used agricultural insecticides experienced increased neurological symptoms, even after they stopped using the products. This neurological problems include headaches, fatigue, insomnia, dizziness, nausea, hand tremor and numbness.
12. Dry mills are usually smaller than wet mills and are built primarily to produce ethanol. Wet mills are bio-refineries and produce a wide range of products, not only Ethanol. Both systems use thermal and electrical powers as their main sources of energy. Wet mills usually generate both electrical and thermal energy from burning natural gas or coal. Dry mills use natural gas to produce steam and purchase electricity from a utility.
13. Corn Ethanol is produce from the starch of the corn. Starch accounts for 66% of the total weight of corn kernels. Then from the total Carbon emissions from the Ethanol production a credit of 586,04 C Kg/ha can be apply. Since the 34% of the emissions will correspond to other by products.
14. During the growing of the crops some soil sequestration is produce, about 0,2 tonne/ha/year which also can be translate into credits of 181,82 C Kg/ha.
15. Ethanol car engine requires 1,56 more Ethanol to achieve the same Gasoline LHV and a Diesel car engine will use 0,08 less Diesel en proportion to Gasoline, all this in terms of L/100 Km.

16. The Kg of Carbon Emissions per 100 Km run in different types of standard vehicles is not so favorable to Ethanol, mainly because of its Low LHV in comparison with Gasoline and Diesel.
17. The use of Ethanol should be internationally regulated because issues like food displacement by fuel demand and fuel efficiencies must be taken into account so that the final impact of the Ethanol is in overall a real benefit to this Planet that we all live in and expect our future generations to have a better environmental situation than the one we have.
18. Biomass is an important source of energy for the future generations and to improve its efficiencies and to make it sustainable is a job of everyone, the climate change is affecting everyone and everybody should take part of this challenge mankind is facing.

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VII. Abbreviations

NCB	Net Carbon Balance
NEB	Net Energy Balance
CO ₂	Carbon dioxide
ARMS	Agricultural Resource Management Survey
ERS	Economic Research Service
USDA	United States Department of Agriculture
ha	Hectare
hrs	Hours
E10	90% Gasoline and 10% Ethanol.

VIII. Tables and Graphs

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- Table n°4. Information source of quantities of farming inputs.
- Table n°5. Carbon emissions from Corn production inputs.
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- Graph n°1. Carbon emissions from Ethanol, Diesel and Gasoline per Gallon.
- Graph n°2. Carbon emissions from NPK.
- Graph n°3. Carbon emissions from Ethanol, Diesel and Gasoline per Gallon with extra N₂O emissions in Ethanol.
- Graph n°4. Carbon Emissions from Lime.
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