

# What is the Carbon Footprint of Cider

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## What is an ecological footprint?

An accounting tool that enables us to estimate how much land a given population needs in terms of the resources it uses and the waste it produces. It is given in land equivalents, because people take resources from all over the world, ecological accounting converts the land requirements our consumption needs into a total area per person, per institution or per country.

## What is a carbon footprint?

An accounting tool that estimates how much carbon a given population produces. Carbon is chosen because of concerns about global warming that carbon dioxide (CO<sub>2</sub> carbon and oxygen combined) accumulating in the atmosphere due to burning fossil fuels creates. The average carbon dioxide produced per year per person in the UK is 11.81 tonnes<sup>1</sup>. The UK government target is to reduce this by 20% in the next few years to 9.4 t, and to reduce it by 60% by 2050 to 4.81t. Many people think this is not a large enough reduction to reduce global warming.

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<sup>1</sup> A carbon footprint can be measured in carbon dioxide or in carbon ( C ) alone, carbon dioxide (CO<sub>2</sub>) is 3.66 times heavier than carbon alone (see below), so to convert from CO<sub>2</sub> to carbon divide by 3.66.

## Why are ecological and carbon footprints important

The use of resources has grown enormously in the last 100 years. This is a result both of population growth and increased use of fossil fuels. The world population for about one million years was less than half a billion. It began to rise around the industrial revolution and by 1800 was one billion, in 1930 it was two billion, today it is more than six billion. It is estimated that at current rates it will be over nine billion in 2050 and that it will ultimately stabilise at 12 billion. It is possible that people will be able to grow enough food to feed this 12 billion population. The world however would not be able to absorb the waste from such a population if it lived at the same standard as a UK citizen today. The main concern today is global warming as a result of carbon dioxide and other 'greenhouse gas' emissions, which would increase with a larger and more affluent population.

## Global Warming

The earth is an extraordinary planet, many crucial factors mean it is unique in the universe in being able to support life. One of the critical factors necessary for life is the earth's atmosphere. The atmosphere consists of a mixture of gasses, it is about 35 miles deep and it stays attached to the earth by gravity.

The lower part, the troposphere, below 6 miles, contains about half the mass of the gasses and all of the water vapour. Above this the mass is less and the air thinner. From about 6 miles to 35 miles is the stratosphere, aircraft on long flights use the lower part of the stratosphere because it is free from clouds, storms, lightning and thunder. Meteorites are burned in the stratosphere, about 12 – 15 miles up. Ozone is at its maximum concentration here, and it absorbs harmful solar radiation. Above the stratosphere is very dispersed gas called the ionosphere which extends for about 200 miles.

The earth's atmosphere consists of:

Substance	Sea Level %	At 30 Miles %
Nitrogen	78.03	79.2
Oxygen	20.99	7.0
Argon	0.94	0.03
Carbon dioxide	0.03 <sup>2</sup>	0
Hydrogen	0.01	13.6
Neon	0.00123	0
Helium	0.0004	0.126
Krypton	0.00005	0
Xenon	0.000006	0
Radon	trace	0

The earth's energy comes from the sun.

Radiation from the sun enters the earth in a variety of wave lengths, some are so small they are measured in Nanometers (nm) which are 1,000,000,000 times smaller (nine noughts) than a metre, i.e. *extremely* small.

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<sup>2</sup> in 1971

Energy waves are classified in the following way:

Radio waves are the longest, longer than 1 metre

microwaves are between 3 and 1 mm

White light – the light of the air around us is made up of a number of different colours (you can see them in a rainbow) which combined together appear colourless to us, each colour has a different length, the longest is red:

infra red	700nm (within the red)
red	640-700 nm
orange	590-640 nm
yellow	570-590 nm
green	500-570 nm
blue	450-500 nm
violet	400-450 nm
ultraviolet	400 nm (beyond the violet)
and then to the very, very small rays	
X rays	10 nm
Gamma rays	0.1 nm
Cosmic rays	0.0001 nm

The sun's energy comes into the atmosphere and to the earth through electromagnetic waves, in the form of short wave length infra red radiation as well as shorter white light and ultra violet radiation. It heats up the Earth. Some of it is re-radiated back, but heat from less hot bodies, like a dying fire, or a warmed up Earth, has a longer wavelength, being largely infra red in length. This type of wavelength cannot pass through glass – so it will heat up a glass house. In the Earth situation some is stopped by the atmosphere, specifically by the small percentage of carbon dioxide in the atmosphere, and reflected back to earth and some escapes the CO<sub>2</sub> beyond into space.

The normal reflection of heat back to Earth is good for life as it keeps the world not too hot and not too cold. However, as our atmosphere absorbs more carbon dioxide less of the long heat wavelengths can escape and the earth heats up.

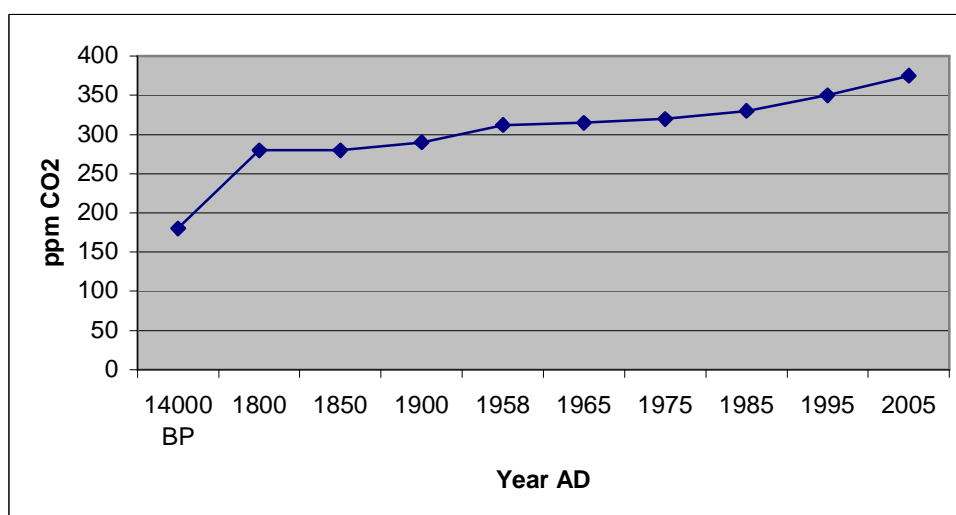
### **The Other Greenhouse Gases**

It is not only CO<sub>2</sub> that absorbs the infrared radiation. Other gases do as well.

Greenhouse Gas	Sources	Time to degrade to another chemical Years	contribution to global warming %
Carbon dioxide CO <sub>2</sub>	Fossil fuels, deforestation, natural sources (rock, sea)	500	49
Methane CH <sub>4</sub>	cattle, decomposition of organic matter, gas leaks	7-10	18

Nitrous oxide N <sub>2</sub> O	fossil fuels, soil cultivation, deforestation	140-190	6
Chlorofluorocarbons (CFC)	Refrigerants, air conditioning, aerosols, solvents	65-110	15
Ozone	photo-chemical processes	one hour in upper stratosphere	12

The burning of fossil fuels has raised the carbon dioxide percentage. Examination of ancient ice from glaciers in Peru, Tanzania and Antarctica that have frozen preserved air in them show that the percentage of carbon dioxide before the industrial age was 280 parts per million (ppm). Since the Industrial Age carbon dioxide has steadily increased in the atmosphere. This is matched by a steady rise in temperature.



### What Is Carbon

Carbon is an element, found in a pure form in graphite and diamonds. It is often known as the 'element of life' because of its ability to form a vast array of compounds found in living things. Although it is not abundant in terms of quantity in the world (<1%), compared to say oxygen, silicon, aluminium and iron or the plant nutrients of potassium, nitrogen, calcium, it is one of the most frequent elements found on earth. It is found in many substances combined with other elements and is an essential component of all plant life. The study of compounds containing carbon is called organic chemistry.

### Valence

All the atoms of elements are made up of electrons with a negative charge, protons with a positive charge and neutrons with no charge. The protons and neutrons form the nucleus of the atom and its mass, the electrons are tiny in comparison but carry an equal charge, they revolve around the nucleus, in comparative terms, at a great distance off.

The electrons revolve around the nucleus in bands called shells, the inner three shells always fill before the outer and take a specific number of electrons. They are numbered from 'k' to 'q' and are filled in the following way.

<b>k</b>	<b>l</b>	<b>m</b>	<b>n</b>	<b>o</b>	<b>p</b>	<b>q</b>
2	8	18	32	below 32	below 12	Below 3

All elements are electrically neutral, so the number of positive protons must equal the number of negative electrons.

Compounds (such as carbon dioxide) are a combination of different elements, one of the ways they combine is through valence, which is a sharing of electrons. Compounds tend to move towards stable structures, which means filled electron shells.

The valence of elements is measured according to the number of elements in their outer shell. Carbon for example is said to have valence of 4, as the four outermost electrons in the *l* shell form co-valent bonds with other elements.

### **What is carbon dioxide**

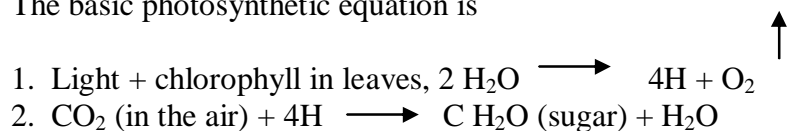
Carbon dioxide is CO<sub>2</sub>, two oxygen atoms and one carbon atom joined with covalent bonds. Carbon has 2 electrons in the *k* shell and 4 in the *l* shell and a mass of 12, 6 neutrons and 6 protons in the nucleus. If it joins with two oxygen atoms which have shells *k* 2, *l* 6 all three atoms will have 8 electrons in the *l* shell, making the molecule<sup>3</sup> more stable than if the three atoms were separate.

Carbon dioxide can form from rocks containing limestone (Ca CO<sub>3</sub>) and also from from animals in their breath and bodies when they die. It also comes from burning organic matter, such as vegetation, coal or oil (below).

### **The Carbon Cycle**

Carbon is the basic building block of all life. In photosynthesis plants take carbon from carbon dioxide in the atmosphere and with the energy from sunlight and the chlorophyll contained in plant cells convert it into cellulose, sugar, starch and protein. The plant returns oxygen into the air.

The basic photosynthetic equation is



Which in words means the energy from light is used by chlorophyll found in green plants to split water into four hydrogen atoms and two oxygen atoms. The oxygen escapes into the air. The hydrogen then combines with carbon dioxide taken from the air to produce sugar and water.

Plants are made of cellulose, lignin, sugars, protein and starch. All these substances are manufactured by the plant using photosynthesis and plus trace elements (e.g.

<sup>3</sup> A molecule is the smallest possible particle of a compound.

Nitrogen, Potassium and Phosphorous) obtained from the air and earth. They are complex carbon molecules consisting of many bonds and many atoms.

Carbon dioxide is eventually returned to the atmosphere by animals who eat plants (which largely consist of complex carbon compounds). The animals may be grazers such as cows or rabbits or minute creatures that live off dead plant material. Carbon dioxide forms in animal cells and is exhaled into the atmosphere.

The carbon cycle is basically in equilibrium, the same amount of carbon is taken out of the atmosphere as is returned to it.

### Fossil Fuels and Carbon Dioxide

The equilibrium state of the carbon cycle described above is disturbed by burning fossil fuels. The carbon dioxide released into the atmosphere is greater than that which is absorbed by plants. Burning fossil fuels releases CO<sub>2</sub> that has been locked up in coal or oil for millions of years.

### Combustion

The Earth consists of 49.9% of Oxygen, it is by far the most abundant element. The structure of oxygen is electron *l* shell 2, electron *m* shell 6, atomic number 8 and atomic mass 16. A substance that combines with Oxygen is always oxidized, this means it loses some of its electrons to the Oxygen, typically 2 electrons would be lost to fill the *m* shell to 8, in which state it is more stable. All such combinations release heat energy. The reaction can be slow, for example the rusting of a nail is slow oxidation and releases heat very slowly, or fast, for example the oxidation of wood, coal or gas which produces flames. Fast oxidation is called combustion.

### Composition of Fuels

Fuels oxidise (burn) and give off heat. Fuels are hydrocarbons, compounds of hydrogen and carbon. There are many types of hydrocarbons:

- Gas which we use for cooking has a variety of forms, some are listed below.
- Coal is a catch all term for decayed and compressed vegetation laid down in deposits 40 to 300 million years ago. Over millions of years it has turned to rock. Its composition depends on how compressed it is, under what conditions and the original constituents of the vegetation:
- Oil or Petroleum is a mixture of different hydrocarbons that are separated to produce a range of different fossil fuels and other products.

Fuel	Manufacture	Carbon monoxide CO	Hydrogen H <sub>2</sub>	Methane CH <sub>4</sub>	Carbon dioxide CO <sub>2</sub>	Nitrogen N <sub>2</sub>	Heating value MJ/litre
Water Gas	From coke	40	50	1.2	4.4	3.8	11.3
Producer gas	From coke	20	21	4	6.8	48	6.7
Coal gas	from coal	4.3	44.8	41	1.1	2.3	26
Natural gas	mining	0	0	84	0	1.0	43.9

Table: Types of Gas

All oxidation (burning) of hydrocarbons produces energy, water vapour and carbon dioxide plus other waste products. The higher energy fuels produce less CO<sub>2</sub> and waste products because a smaller amount needs to be burnt for the same amount of energy.

Listed below is the energy value of common fuels when burnt by efficient techniques that retain the heat from the water vapour produced during burning. The amount is measured in M = mega = 1,000,000 joules. A joule is a measure of heat and energy. There are 4.184 joules in a calorie. A calorie is the amount of heat needed to raise 1cm of water by 1 degree centigrade.

The CO<sub>2</sub> emissions per kilowatt hours (kWh) of one form of energy, electricity are given below. A kilowatt is a measure of electricity, it is one thousand watts, one watt is one joule (see joule above) per second. A light bulb will tell you how many watts it uses; a 60 watt (per second) light bulb gives a low light, a 150 light bulb is much brighter. A kettle will use a thousand watts for about five minutes to boil. Electricity is generally measured in kilowatt (kwatt) hours. The fuels at the top of the table will release considerably less CO<sub>2</sub> than those at the bottom of the table because they give out more energy per kilogram than fuels at the bottom of the table. However, it should be born in mind that wood and charcoal, though low in energy are ‘carbon neutral’ because growing wood on a 25 year cycle absorbs as much carbon dioxide as it gives off. All the other fuels were formed thousands (or hundreds in the case of peat) of years ago, and are releasing stored carbon into the atmosphere. There is now more carbon in the atmosphere than plants can take up.

<b>Fuel</b>	<b>MJ/kg</b>	<b>Carbon content<sup>4</sup></b>
Methane (gas)	55.5	0.49kg carbon/1 cubic metre gas
Propane	50.3	
Petrol (called Gasoline in US)	47.3	2.9kg carbon/gallon converting to carbon dioxide and litres, this is 2.5kg CO <sub>2</sub> /litre
Anthracite	32.500	
Coke	28 – 31	
Bituminous coal	17 – 23.2	
Coal	15 – 27	746kg carbon/tonne
Charcoal	29.6	

<sup>4</sup> From [teesforest.org.uk/R&REnergy.conv.htm](http://teesforest.org.uk/R&REnergy.conv.htm).

Wood (dry)	14.4 – 17.4	
Peat	13.8 – 20.5	

Taken from [http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d\\_169.html](http://www.engineeringtoolbox.com/fuels-higher-calorific-values-d_169.html)

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## The Cider Trade in Herefordshire and Carbon Dioxide Cycle

### What is cider

Cider is apple juice that has fermented to produce an alcoholic drink. Chemically alcohol is an organic chemical, i.e. one that contains carbon. Typically it consists of a molecular group containing one oxygen and one hydrogen attached to a carbon atom that is attached to three other atoms which are one carbon and two hydrogens (primary alcohol) or two carbons and one hydrogen (secondary alcohol) or three carbons (tertiary alcohol). Ethyl alcohol (C<sub>2</sub>H<sub>5</sub>OH) is the type of alcohol found in beer, gin, wine and cider.

Alcohol was one of the earliest inventions of people, used by them to raise the spirits, deaden mental and physical pain and to have fun. There is evidence that it was drunk in prehistory and our earliest documentary sources show how important it was. The Romans drank wine and the Anglo-Saxons beer. One of the first English stories ever written 'Beowulf', dating from the 8<sup>th</sup> century or earlier and recently transcribed by Seamus Heaney describes the drinking hall.

So, after nightfall, Grendel set out  
for the lofty house, to see how the Ring-Danes  
were settling into it after their drink,  
and there he came upon them, a company of the best  
asleep from their feasting, insensible to pain  
and human sorrow.

p.6 Beowulf, a New Translation by Seamus Heaney

The earliest written record for cider in England is about 1200, but it was no doubt made before this, because apple juice turns very quickly into alcohol and people would have noticed this and used it.

The fermentation happens naturally due to yeasts (minute fungi) the spores (a type of seed) of which are present in the air all around us but are so small they cannot be seen. The yeast grows on sugars naturally present in the apples. In the past people left the apple juice in a wooden barrel and the yeast arrived naturally, nowadays the larger cider firms introduce selected yeasts into the apple juice and control the fermentation. The alcoholic content is measure by the percentage alcohol, English beer for example varies from 3% to 5%, wine is stronger (and is drunk in smaller glasses), and is about 12%. Cider is generally drunk in similar quantities to beer, in pint or half pint glasses but it is stronger, bottled cider can be 7% or 8%, draught cider is about 5%-7%.

Cider is made by crushing cider apples, these are small apples with a high tannin content, to obtain the juice, leaving it to ferment, and putting it in barrels to mature. Though many things can go wrong (e.g. the wrong yeasts will lead to a nasty flavour), it is basically a simple process.

In the past producing cider would have had virtually no carbon footprint at all, because it was done using manual labour which gets its energy from plants (all food, even meat, eaten by people or draught animals ultimately comes from plants) which takes as much CO<sub>2</sub> from the atmosphere as it gives off (see photosynthesis above). It used no fossil fuels (coal, oil, gas, etc.). The crushing was done by horses or people pushing a big stone around a stone trough (called a mill) and the energy for this was obtained by food grown ultimately from plants. The cider was fermented in wooden barrels produced by trees that are a renewable resource, the only non renewable resource in the process would be the coal used to smelt and forge the iron that created the axes and other iron tools. Before the 19<sup>th</sup> century this would have been smelted with charcoal, so even this would have been a renewable resource.

Herefordshire has a history of producing cider, it is home to the biggest cider producer in the world (Bulmers) plus many smaller cider and perry makers. Bulmers (now owned by Scottish and Newcastle) employs about 300 people in Hereford City and the smaller producers bring cider visitors into the county.

The UK produces 5 million hectolitres, one hectolitre is 100 litres, one litre is 0.22 of a gallon, so this is 500,000,000 litres or 110 million gallons of cider a year. The production has grown enormously in the last 30 years. In 1975 the UK produced 2 million hectolitres. Bulmers produces over half the UK total.

### **Calculating the Carbon Footprint of Cider**

To calculate the amount of Carbon dioxide produced by making cider is in theory simple. You find the inputs, the amount of fuel and materials, and measure how much CO<sub>2</sub> each produces. You off set this against any CO<sub>2</sub> that the process absorbs. It is the same method that is used for all carbon footprint calculations.

#### **Unit of Measurement**

Carbon dioxide output may be given in tonnes or kilograms of carbon dioxide as tCO<sub>2</sub> or kgCO<sub>2</sub> or in tonnes or kilograms of carbon, tC or kgC. If you go back to your chemical equations it will be clear that a tonne of Carbon C (mass 12) is a much smaller figure than a tonne of carbon dioxide (atomic mass 40). However, the mass weight of elements is an ideal number, many carbon and oxygen elements have extra neutrons in the nucleus adding to the weight of the element. Atoms that have differing numbers of neutrons are called isotopes. Samples of the elements have a certain average percentage of isotopes, and their presence makes the atomic weight slightly different. Including the isotopes the average atomic weight of oxygen is 15.999, and the average of carbon is 12.011. So CO<sub>2</sub> has atomic mass of 44.009 and carbon 12.011, making the conversion 3.66.

There are two processes in making cider, orcharding – growing the apples, and making the cider.

#### **Orcharding**

For the following calculations I have used Rowley Orchard, a 100 acre orchard (51 ha) near Leominster, run by John Moss (recently retired) for 25 years, who has kindly supplied the following figures.

## Travel

Different cars have different outputs of CO<sub>2</sub>. You can look them up on [www.vcacarfueldata.org.uk](http://www.vcacarfueldata.org.uk).

Here are a few:

<b>Make</b>	<b>grams CO<sub>2</sub>. per kilometre</b>
Peugot 107 Petrol	109
Volkswagen Polo, petrol	134
Skoda Fabia Hatch back, petrol	144
Subaru, 4 door, petrol	206
Landrover Discovery 3, diesel	249
Toyota Landcruiser 1	305

NB: To convert miles to kilometres multiply by 1.60934; there are 4.55 litres to gallon

Recent European Commission guidance is seeking to put a limit of 130gram/km for all manufacturers. The target was for 120 grams per km by 2012 but the commission has bowed under pressure from car manufacturers to a higher limit. They complained that Audi, Porsche, BMW and other powerful cars would go out of business if the 120 g limit was imposed.

Under the voluntary commitments, European manufacturers have said they will reduce average emissions from their new cars to 140g CO<sub>2</sub>/km by 2008, while the Japanese and Korean industries will do so by 2009. For vans, the fleet average emission targets would be 175g by 2012 and 160g by 2015, compared with 201g in 2002. From 1995 to 2004 average emissions from new cars sold in the first 15 member states of the EU (EU-15) fell from 186g CO<sub>2</sub>/km to 163g CO<sub>2</sub>/km. so there is still some way to go and it will be interesting to see how the car industry responds.

For the Rowley Orchard example a number of people travel to work. These include the manager John who would go most days, and a number of employees who share cars and travel to work during the picking and pruning season.

John has worked out that in a typical year there are 1,117 journeys by employees, they travel an average of 55 miles using 4 cars. In the table below these figures have been converted to kilometres (1.609 km in one mile) and an average emission rate for a car of 175g/km has been used.

In addition to employees travel the apples are taken by lorry to the Magnus factory in Ireland. This involves 63 lorry trip travelling 371 miles by land and 100 miles by sea, for a one way journey. The rail freight association has calculated that the CO<sub>2</sub> emission of carrying freight by Heavy Goods Vehicle (HGV) is 180g/t/km. The Department for Transport has a website (n/e/r/a) that estimates for a lorry carrying 20 tonnes averaging 50 m.p.h. it is 670g/km.

The lorry trip from Kimbolton to Magners in Ireland is 597 km carrying 20 tonnes, so using the n/e/r/a/ figures one trip will be 597 x 670g which is 0.4t CO<sub>2</sub>. Using the RFA figures it is 597 x 20 x 180g which is 2.15t CO<sub>2</sub> full. For empty loads a 350g/km figure is taken (size of a large car) which is 0.2t. Averaged together it is for a return trip 1.12t. The figures are very different. Here the DfT figures are used with the empty lorry assessed at 350g, giving 0.6t CO<sub>2</sub> per one trip.

The ferry journey has been estimated by a carbon footprint calculator (Mark Lymas)

Travel:		Converted to km	t CO <sub>2</sub>	t C <sup>5</sup>
Days travelled	279 <sup>6</sup>			
Distance miles	55	88.5		
No of cars	4		17.28	4.7
lorry loads	63			
Lorry loaded one way at 20t, return empty @ 0.4t/trip	371	597	25.2	6.9
sea distance miles	100	160.9	75.6	20.7
Engineer visits no.	22			
Distance travelled by engineer miles	48	77.2	0.3	0.1
chain saw petrol gallons	4		negligible	
cherry picker gallons	32		negligible	
Total petrol			118	32

## Fertiliser

Orchards require fertilisers and pesticides. At Rowley and other orchards growers are reducing these inputs as much as is possible, nevertheless some has to be used to get the yields and quality cider producers demand. Producing fertiliser takes a large amount of fuel. Conversion figures on the amount of CO<sub>2</sub> produced during the production phase are hard to find but two people T Jenssen and G Kongshaug have produced figures for the Fertiliser Society. These are the figures they give:

Fertiliser	World M t	GJ/t	CO <sub>2</sub> M t yr	CO <sub>2</sub> /kg	C/kg
Nitrogen	83.1	47.4	261	3.141	0.9
Phosphorous	31	47.0	10	0.323	0.1
Potassium	20.8		8	0.385	0.1

A M t yr is mega tonnes per year, a mega M means one million 1,000,000

It can be seen from this table that Nitrogen fertiliser costs a lot in energy terms, since it is produced using the Haber process. A heated mixture of hydrogen (H) and nitrogen (N) is passed over a catalyst under pressure resulting in ammonia (NH<sub>3</sub>) which is then used to make fertiliser. P and K are normally obtained from rock deposits by quarrying, then shipped around the world for use.

A paper by Sam Wood and Annette Cowrie, (2004) A review of greenhouse gas emission factors for fertilizer published on line shows how complicated it is to

<sup>5</sup> Divide CO<sub>2</sub> by 3.66 to get equivalent in carbon.

<sup>6</sup> Total number of days worked is 1117 in the year for four people, using four cars, travelling 55 miles

estimate the greenhouse gas emissions during the production of NPK fertiliser. Nevertheless the figures they give for 1kg N are broadly 1.15kg to 2.2kg CO<sub>2</sub>, for 1kg P it is 0.3kg CO<sub>2</sub>, for 1kg NPK it is 2kg CO<sub>2</sub>. They are broadly similar to the Fertiliser Society.

A variety of pesticide, fungicides and herbicides are used in addition to the fertilisers. Because the amount of CO<sub>2</sub> that is produced in the factories where they are made is not known, for this calculation the P Phosphorous figure is used as it is the lowest.

At Rowley fertiliser is applied at 1 cwt N per acre 0.75 cwt per acre of P and K; this is approx 51kg N, 36.7kg P and K per acre

Inputs		Kg CO <sub>2</sub> /kg fert	Total tCO <sub>2</sub>	Total tC
Area acres at Rowley	100			
N/kg/acre	51	3.141	0.160	0.044
P/kg/acre	36.7		0.012	0.003
K/kg/acre	36.7		0.014	0.004
Radspore litres/acre/yr	9		0.003	0.001
Inder litres/acre/yr	3.5		0.001	0.000
Topas litres/acre/year	4.5		0.001	0.000
Captan kg/acre/year	12.3		0.004	0.001
Romieland litre/acre/yr	2.5		0.001	0.000
Dursban litres/acre/yr	4		0.001	0.000
Calypso litres/acre/yr	0.14		0.000	0.000
A Fox kg/acre/yr	0.226		0.000	0.000
Total Fertilisers and Herbicides per acre	160.576		0.198	0.054
<b>Total F and H per 100 acres</b>			<b>19.781</b>	<b>5.405</b>

In addition to the fuel and fertilisers there is machinery bought for the orchard. These are omitted in these calculations.

Total		t Co <sub>2</sub>	t C
Total petrol		118	32
Total fertilisers, herbicides, fungicides and pesticides for 100 acres (51 ha)		19.8	5.4
Total:		137.8	37.4

### Orchard Outputs

Against this must be set the outputs. Trees produce at a different rate, depending on their age, the weather and other factors. John Moss has estimated an average for Rowley of 16t/acre, making the output for the 100 acres 1,600 t. This produces 240,000 to 288,000 gallons of cider which is 1,090,909 to 1,309,090 litres of cider.

In addition trees absorb or 'sequester' carbon dioxide, making it into wood (see photosynthesis above). Trees are basically lignin (C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>) and water (H<sub>2</sub>O). One kg of wood is made from CO<sub>2</sub> and water and trace elements. Because of the different weights of atoms (carbon 12, hydrogen 1, oxygen 16) and because about 40% of a tree consists of water, 1kg of wood has taken about 1kg of CO<sub>2</sub> to make. An apple tree in 0 to 25 years may reach a weight of 0.5 t, converting the relatively heavy CO<sub>2</sub>

molecules, into complex molecules made up mainly of C and H such as cellulose and lignin, and releasing oxygen in the process. Modern bush orchards have a life of 50 to 80 years. Modern orchards are planted at 120 to 180 to the acre. If there were 150 to the acre this would be:

$(150 \times 100 \text{ (acres)} \times 0.5 \text{ ton})/25$ , this is 300 t CO<sub>2</sub> or 82t C in a year.

So our 137.8 t CO<sub>2</sub> or 37.4 t C for the 100 acres of Rowley Orchard are actually absorbing more CO<sub>2</sub> than they are giving off:  $300 - 137.8 = 162.2 \text{ t CO}_2$ .

However, 'carbon sequestration' is a bit of a panacea, or a 'false dawn' so far as climate change is concerned. It must always be remembered that it only works so long as the trees are alive, and their wood is not rotted down, going back to nature, and the CO<sub>2</sub> released back into the atmosphere. One solution might be if we made very large applewood chairs and kept them for 200,000 years until the climate crisis abated a little.

### **The Carbon Footprint of Cider Making**

This section has not yet been completed.

#### **Sources Used in This Essay**

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### **Appendix 1: Carbon Content of Fuels**

From [www.teesforest.org.uk/R&REnergy.conv.htm](http://www.teesforest.org.uk/R&REnergy.conv.htm)

- Coal (average) = 25.4 tonnes carbon per terajoule (TJ)
- metric tonne coal = 746 kg carbon
- Oil (average) = 19.9 tonnes carbon / TJ
- Carbon emissions from gasoline (petrol) = 2.9 kg carbon / UK gallon
- Carbon emissions from diesel or fuel oil = 3.3 kg carbon / UK gallon.

Another way of expressing this = roughly 2.5 kg CO<sub>2</sub> per litre of fuel used

N.B. LPG (liquefied petroleum gas) has about 10% less carbon content than petrol and diesel

- Natural gas (methane) = 14.4 tonnes carbon / TJ
- cubic meter natural gas (methane) = 0.49 kg carbon
- Carbon content of bioenergy feedstocks: approx. 50% (about 28 tonnes carbon / tj) for all forms of wood and woody crops; approx. 45% (26 tonnes / tj) for grassy crops and agricultural residues . N.b. there are no net carbon emissions from the use of bioenergy fuels, assuming that the fuel is harvested on a sustainable basis with regrowth.