Climate Change.
What is it and what can the oil seed industry do about it?

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My name is Alan Paine and I am a chemical engineer who has been working in the edible oil industry since 1984. Much of my career has been involved with the design of vegetable oil refining equipment but at the same time I have been following the debate about global warming and trying to understand some of the issues about this controversial subject.

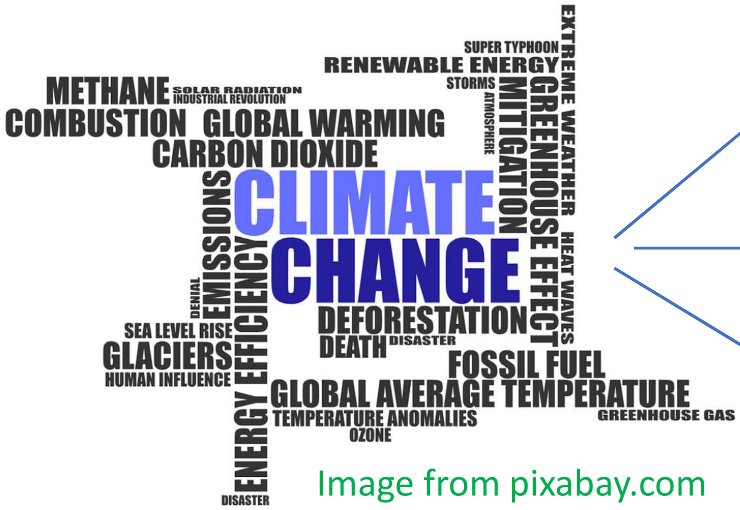

Image from pixabay.com

The basic science behind climate change

How the edible oil industry can reduce it's own impact

The use of biofuels derived from vegetable oils

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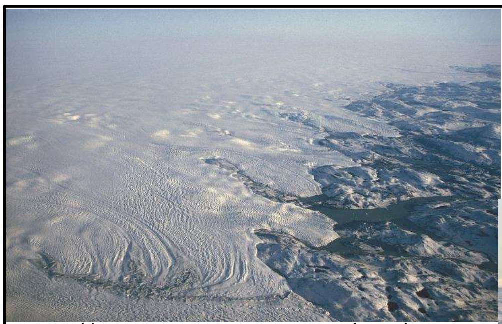
Climate change is a very complicated as illustrated by this image from pixabay.com which by the way is a very useful source of free pictures. Of course it would be impossible in a short talk to cover the whole subject in detail so I'm going to divide this presentation into three sections covering the basic science behind why and how we believe the world is getting warmer, what the oil processing industry can do to reduce its own footprint and save energy in an economically sustainable way and the role that biofuels can play in replacing petroleum based products. But I hope that you will find the general principles that I'm going to talk about interesting even if you not involved in the vegetable oil industry

Annual snowfall in polar regions turns to ice trapping air bubbles



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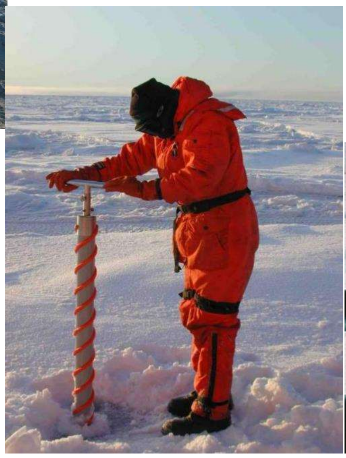

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http://cdn.antarcticglaciers.org/wp-content/uploads/2013/10/Icecore_4.jpg

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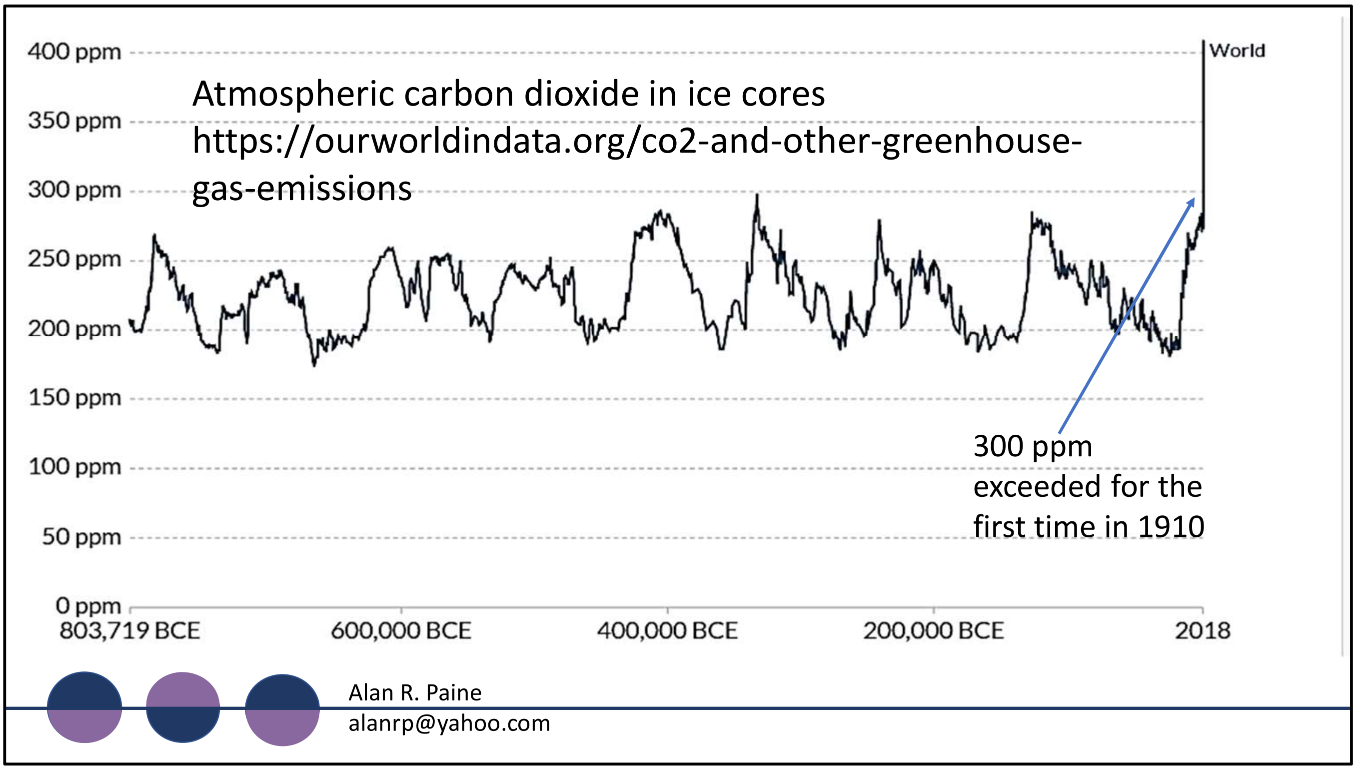
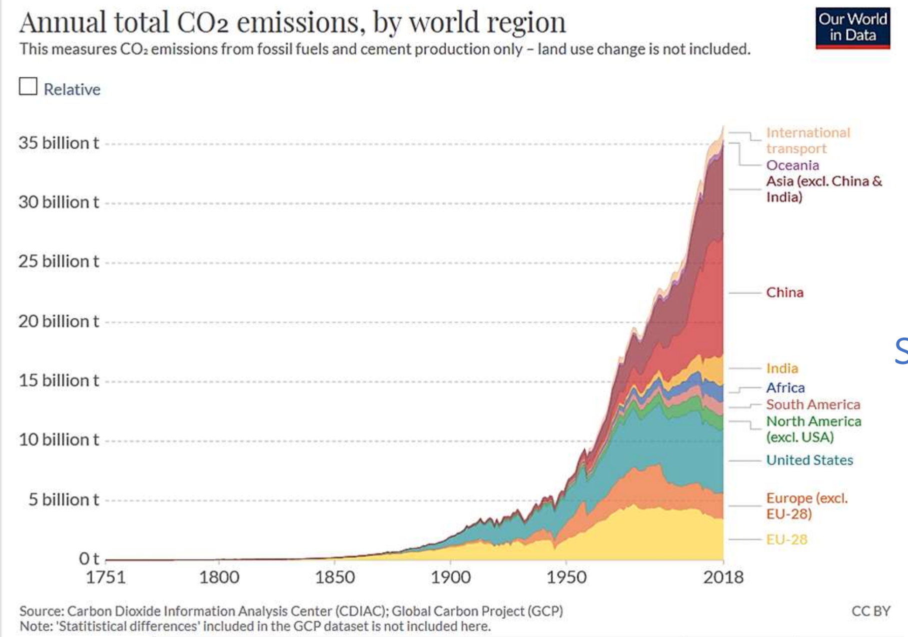
So what's all the fuss about and how do we know what's going on? In parts of the Arctic and Antarctic winter snow fall does not fully melt in the summer and turns to ice trapping air bubbles with it. Hardy scientists have drilled down into the ice, extracting long cylindrical cores and then analysed the air in the bubbles to see how much carbon dioxide was in the atmosphere at the time.



And the result is fairly surprising. By carefully counting the annual layers of ice the oldest cores have been dated to eight hundred and three thousand, seven hundred and nineteen years before the common era . For most of the time from then until now the level of carbon dioxide has varied between 200 and 250 ppm until, in the industrial revolution, the graph starts a near vertical rise passing 300 ppm in 1910 for the first time in over 800,000 years. We have now reached over 400 ppm and are heading for double the long term average.



Rise in carbon dioxide emissions since the industrial revolution

https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

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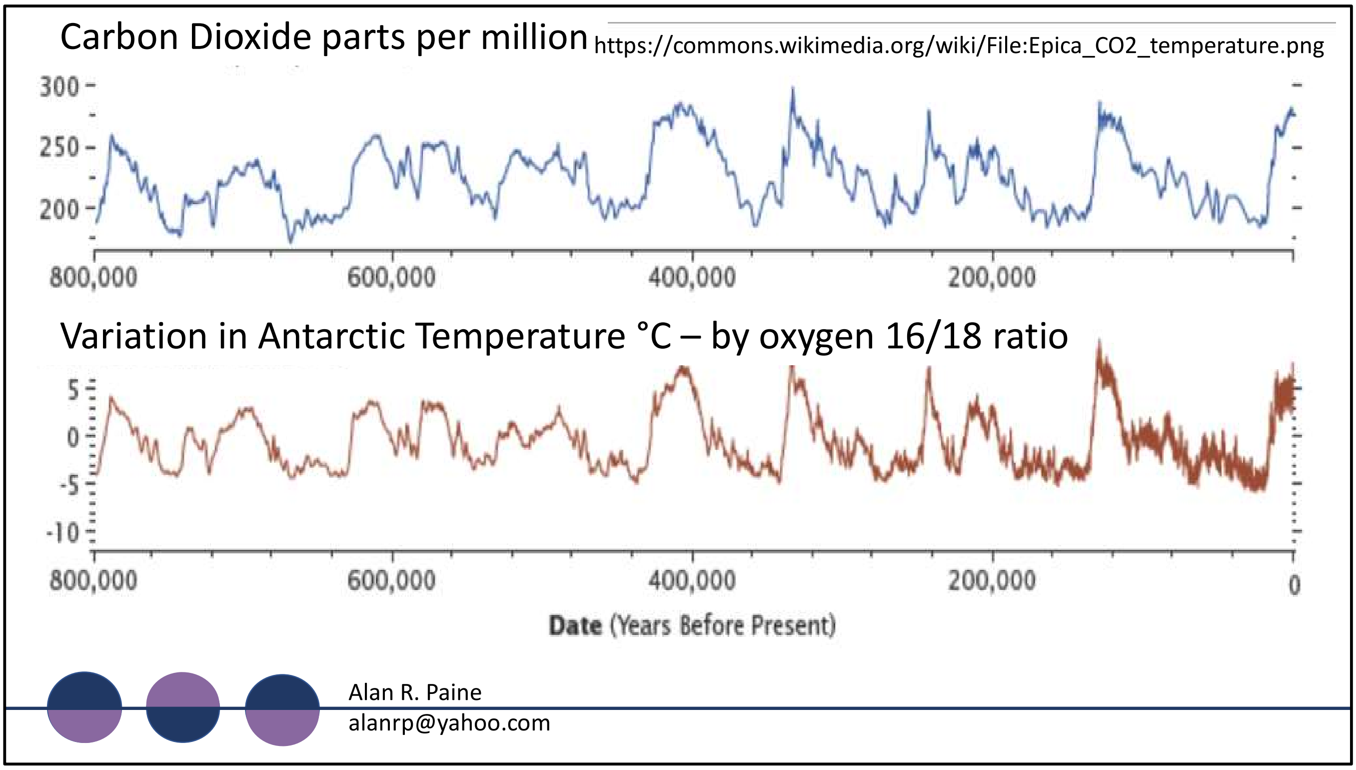
Hundreds of years ago fossil fuel use was very small and it only started to rise off the bottom of the graph in about 1850. Carbon dioxide emissions from fossil fuel use have risen by about 100 x since then reaching over 36 billion tonnes in 2018. The current pandemic has led to a fall in emissions but only by 6.4 % in 2020 according to the journal Nature.

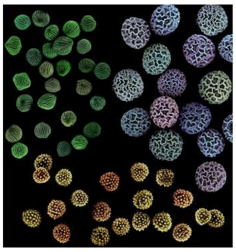


So why is the amount of carbon dioxide in the air anything to worry about? The answer is that there is a close link between world temperature and the amount of atmospheric CO2 and if the level today is exceptionally high then we can expect that to lead to exceptionally high temperatures. Oxygen mostly consists of two types or isotopes, oxygen 16 and oxygen 18. Water containing oxygen 18 is heavier than water containing oxygen 16 and the heavier type is more likely to precipitate out of clouds the colder it is. Therefore when it was colder the Antarctic snow contained more oxygen 18 than when it was warmer. We can use this data to show how the temperature has varied over the past 800,000 years and see that there is a remarkable correlation between atmospheric carbon dioxide shown by the blue line and the temperature in the Antarctic shown in red.

Some methods used to determine ancient climate

pixabay.com

Oxygen 16/18 ratio in sea shells



https://commons.wikimedia.org/wiki/File:Three_Species_Pollen_Grains.jpg

Pollen in lake sediments

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Tree rings

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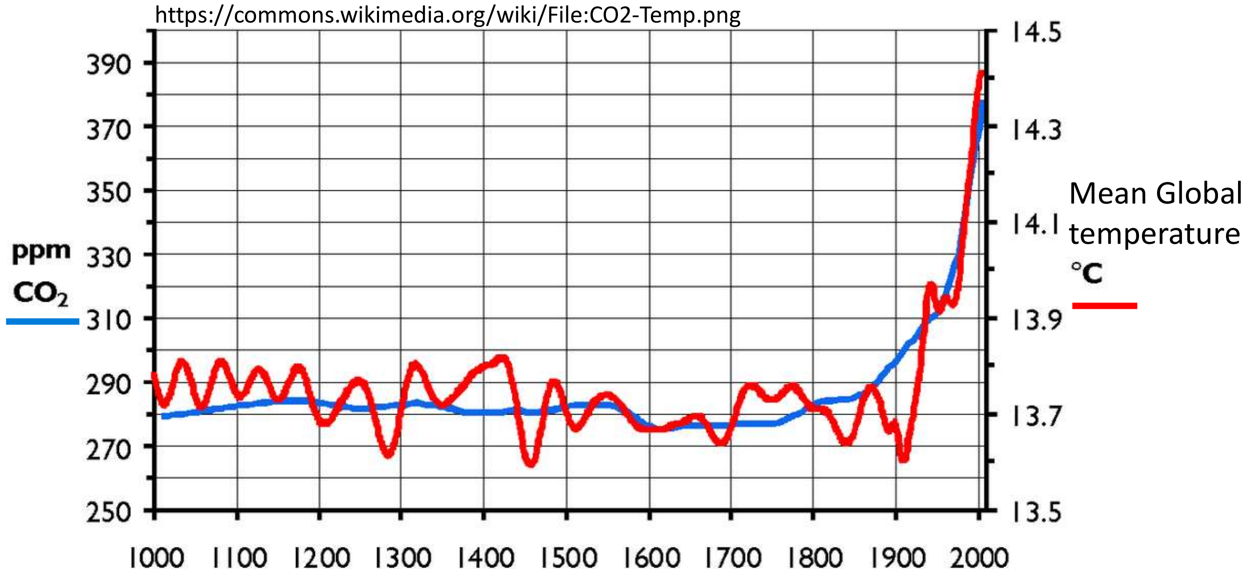
Outside of the polar regions there are other methods that can be used to determine what temperature it was in the past including the ratio of oxygen 16 and 18 in sea shells, pollen deposits showing what types of plants were growing in a particular time and place and variations in tree rings https://commons.wikimedia.org/wiki/File:CO2-Temp.png



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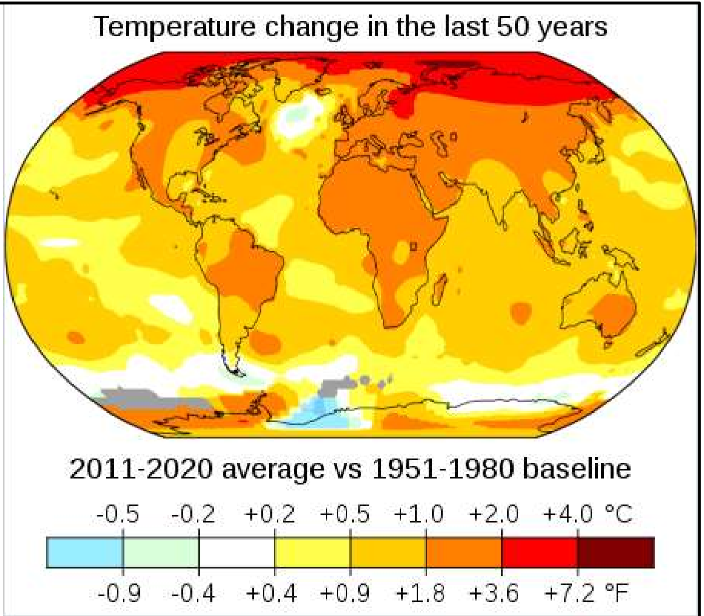
Putting archaeological evidence together with historical records we can get an idea of what has happened over the last thousand years. The graph shows a steady level of carbon dioxide in the atmosphere, indicated by the blue line, from the year 1000 until about 1850, when it began a steep rise. Global temperature, indicated by the red line has stayed close to 13.7°C from 1000 until about 1900 when it started to rise steeply reaching 14.4°C by the year 2000. It has continued to rise and the last decade has been the hottest ever recorded.

The temperature rise is not even across the world



Average global temperatures from 2010 to 2019 compared to a baseline average from 1951 to 1978. Source: NASA.

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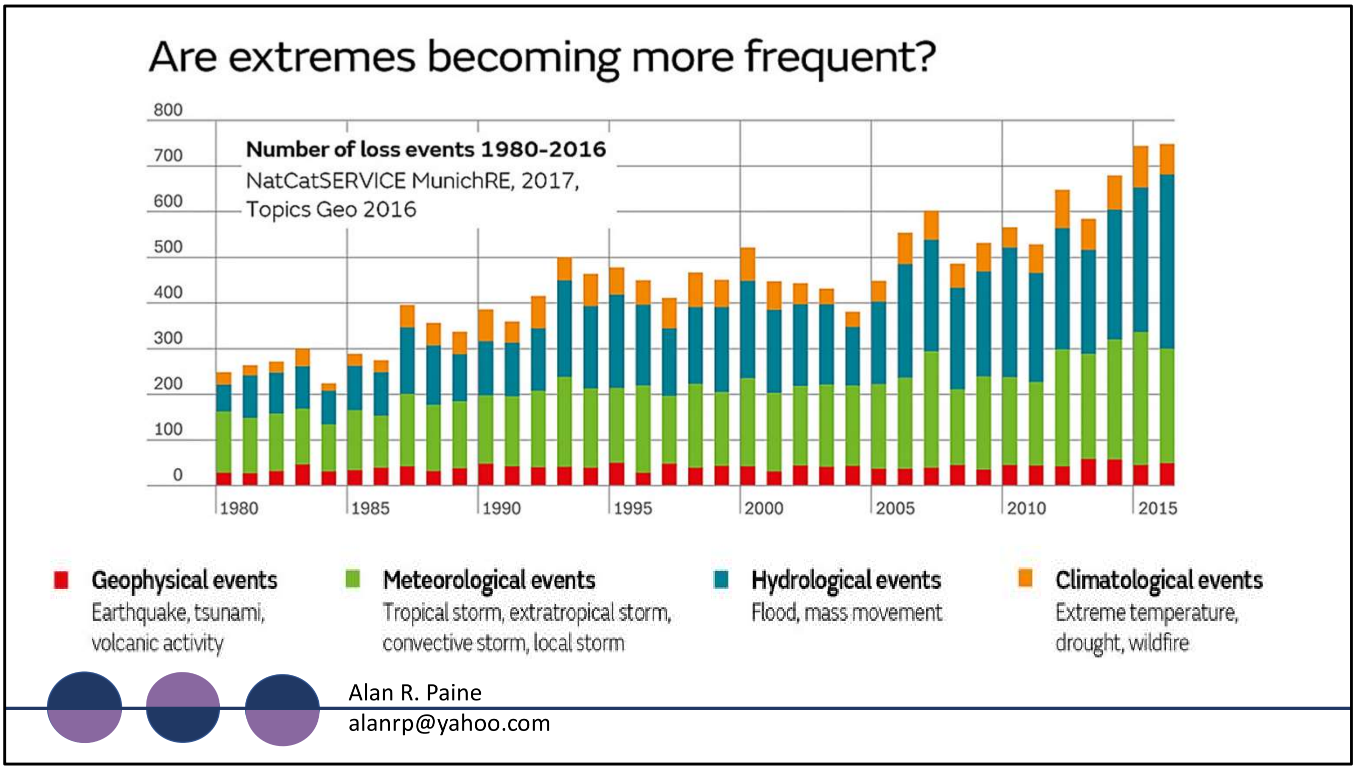
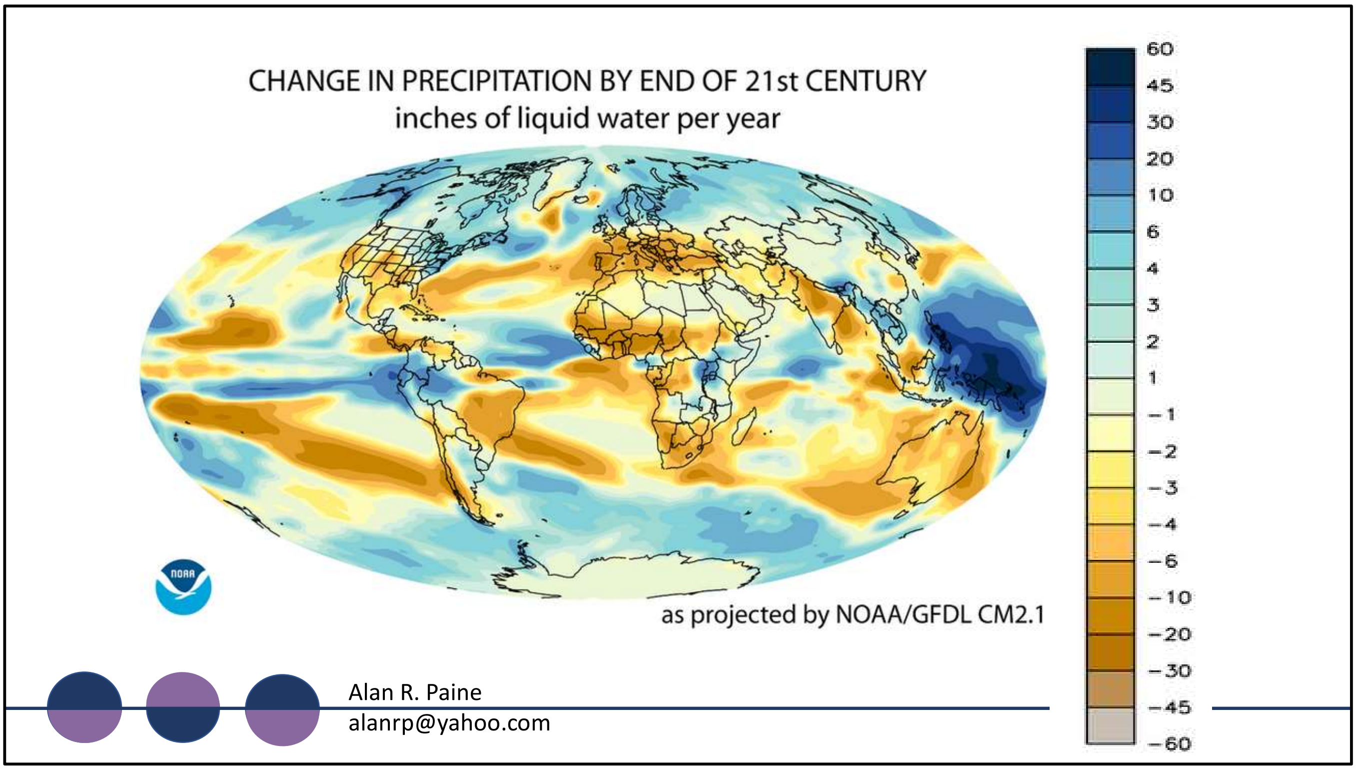
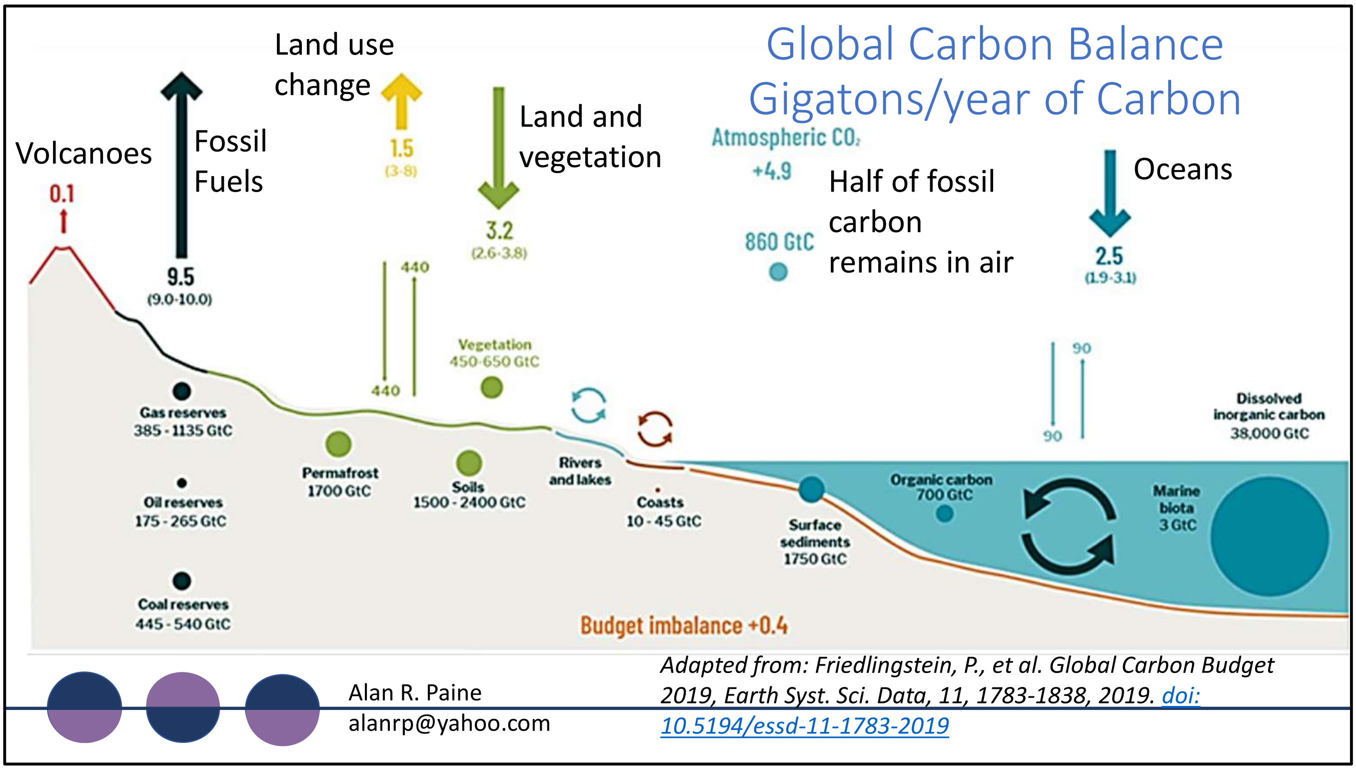
Why do we have to worry about a rise of only around 1°C? It doesn't sound like very much. One of the problems is that the distribution of that rise has not been even which has caused some Northern polar regions to gain more than 2 °C in only the past 50 years



Even more alarming is that extreme weather events are becoming more common. One investigation into natural disasters showed that weather linked events such as storms, floods, droughts and wildfires increased by 3x just between 1980 and 2015.



We can’t be sure exactly what will happen in the future but a study by the National Oceanic and Atmospheric Administration or NOAA indicates that if current trends are allowed to continue then by the end of the 21st century not only temperatures will change but the world will experience dramatic shifts in rainfall patterns. The scale here is in inches of water per year and a drop of 20 or more inches, or half a metre is predicted in some parts of the world leading to great problems in food production. We are also at risk of sea level rises affecting many populated areas that currently lie very close to the coast.



A question we need to ask is - how do we know that rising levels of carbon dioxide are causing rising temperatures and not the other way round? An important clue is that the extra carbon dioxide contains very little radioactive carbon 14 which is the basis of radio carbon dating. The half life of carbon 14 is 5730 years so that fossil fuels which have been under the ground for millions of years contain hardly any but biologically derived carbon in the sea contains a significant amount.

This diagram shows a simplified view of the global carbon balance. It's important to note that the flows are gigatons or billions of metric tonnes per year of carbon, not carbon dioxide which weighs 3.7 x as much. About a half of the 9.5 gigatons released from fossil fuel use stays in the air, some is dissolved in the ocean and some is incorporated into land and vegetation. An encouraging sign is that higher levels of carbon dioxide seem to be stimulating plant growth but not enough to fully offset the increase.

Net Zero Carbon?

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The UK and an increasing number of other countries and organizations have declared the goal of achieving net zero carbon emissions by 2050 or a similar date in order to keep the atmospheric carbon dioxide levels below 450 ppm and the mean global temperature rise to below 2°C as required by the Paris Accord. But it's a big job and we have to deal not only with current emissions but also the rise in emissions that will take place if we do nothing. Increasing population and increasing demand per person as poorer countries develop mean that by 2050 people could be putting 40% more carbon dioxide into the air than at present unless we do something about it and this adds up to about 50 gigatons per year of carbon dioxide compared with the current figure of around 35 gigatons per year.

Getting to net zero by 2050

Geoff Maitland professor of Energy Engineering Imperial College London

**Doing nothing =
50 gigatons/year
CO_2 in 2050**

25 gigatons/year reduction by energy efficiency and more gas

15 gigatons/year reduction by more renewables and nuclear

10 gigatons/year reduction by carbon capture and storage

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In an article in 'The Chemical Engineer' September 2014 Geoff Maitland professor of energy engineering at Imperial College London sets out in a clear and practical way how to reduce emissions by 50 gigatons/year. Stopping the use of fossil fuels in such a short time is not possible and he proposes three broad steps.

Half the required reduction or 25 gigatons/year could achieved by using energy more efficiently and increased use of natural gas. 15 gigatons could be saved the use of renewable energy and nuclear power but even after we have done all of that we would still have to capture 10 billion tonnes per year of carbon dioxide in situations such as coal fired power stations, liquify it and store it underground.

Easier said than done

https://ijboudreaux.files.wordpress.com/2015/09/titanic_sinking_atlantic.jpg

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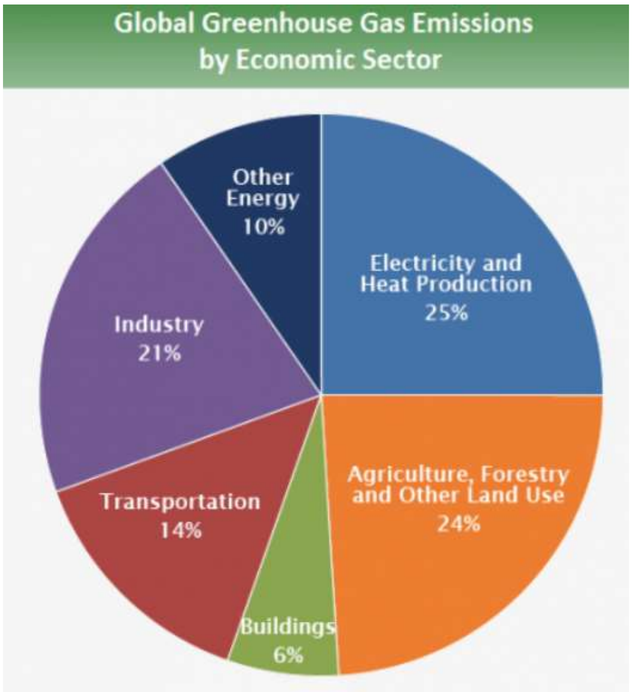
Of course all of this is easier said than done and although I hope we are not in quite such a desperate situation as the people on the Titanic it is going to be a huge task to make a substantial reduction in carbon dioxide emissions let alone bring them to zero.

All parts of the economy are making a contribution



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https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

All parts of the economy are contributing to green house gas emissions and no one sector is outstandingly bad so it’s important for all areas to do what they can to be more efficient.

What can we do in the oilseed business?

- **sustainable farming**
- **low energy processing**
- **Renewable Fuels**

pixabay.com

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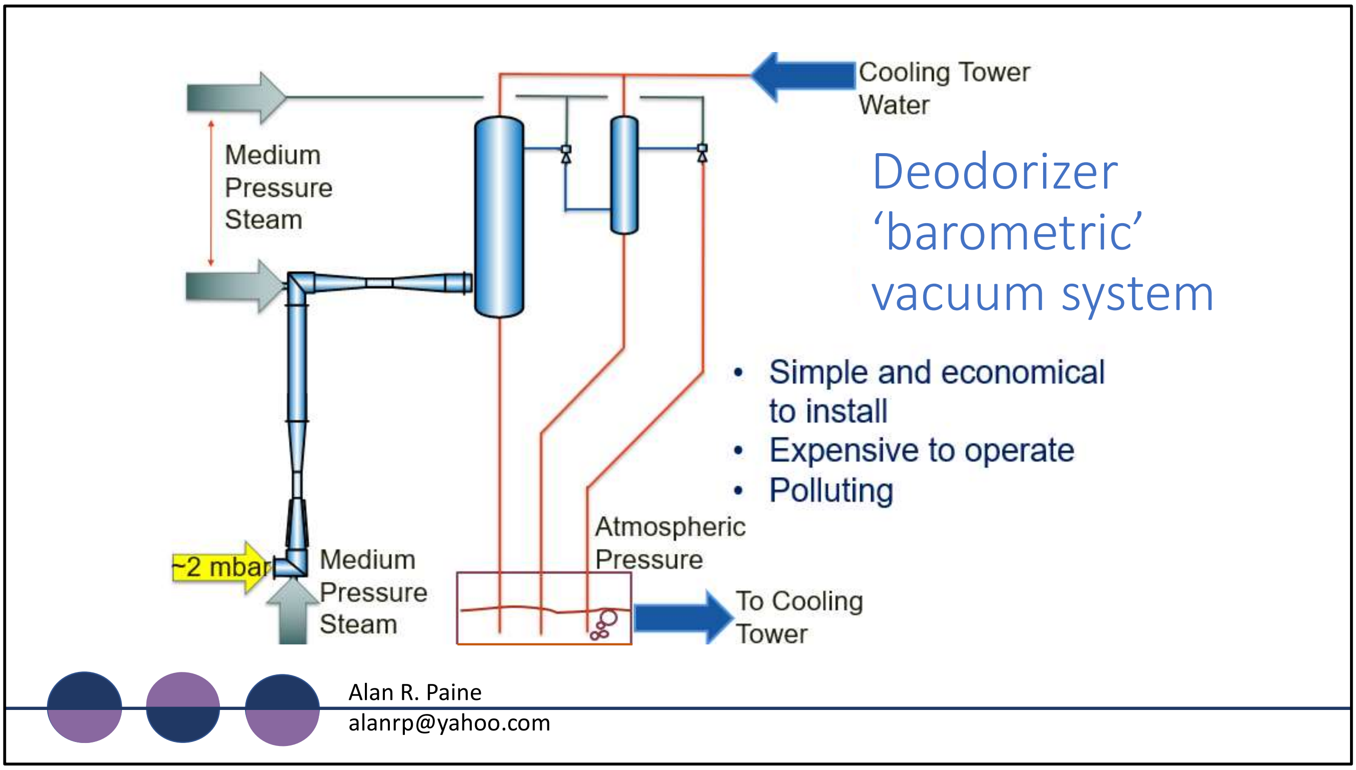
So what can we do about climate change in the vegetable oil industry? Agriculture is a very competitive business and farmers are always aiming to save energy and reduce fertilizer use. Increasing numbers of farmers are using sophisticated technology including satellite tracking to improve efficiency. In the right circumstances oil palms can help to sequester carbon from the atmosphere in spite of the bad press that palm oil often gets. In oil processing there have been very impressive energy savings over the last few decades but there is still more that can be done and vegetable oils are also playing a role in producing renewable biofuels.

In many sectors including the vegetable oil industry we have seen huge savings in energy use over the years that have been driven purely by economics and not by any desire to 'save the planet' and in the future there are still more things we can do to improve efficiency and save money whether we believe in climate change or not.

I'm now going to change the focus and look very specifically at some issues in edible oil refining which happens to be my speciality. If you are working in other areas you will probably be able to find similar ways in which emissions can be reduced. Even if you think that you are doing everything possible to save energy it is likely in future that energy will become more expensive making it easier to justify spending more on efficiency.



Deodorizing vegetable oil uses a lot of energy in refineries. The oil has to be heated up to a temperature of around 250°C and also exposed to a low pressure of a few mbar while having steam bubbled through it. The picture shows the so called 'barometric' vacuum system used for maintaining a low pressure inside a deodorizer. It is the cheapest one to buy and widely used in spite of being expensive to run and highly polluting.

Vacuum Skimming Pond

Tail pipes from vacuum equipment

Fatty matter floating on dirty water

Pond often occupies large amount of land

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The vacuum skimming pond is a familiar sight in many refineries. Fatty matter in the dirty water circulating in the vacuum set is allowed to float to the surface where it can hopefully be skimmed off but even the most efficient skimming systems leave a significant amount of organic matter in the water which gives off a bad smell as it passes through the cooling tower.

Dirty Water Cooling Tower

Air in

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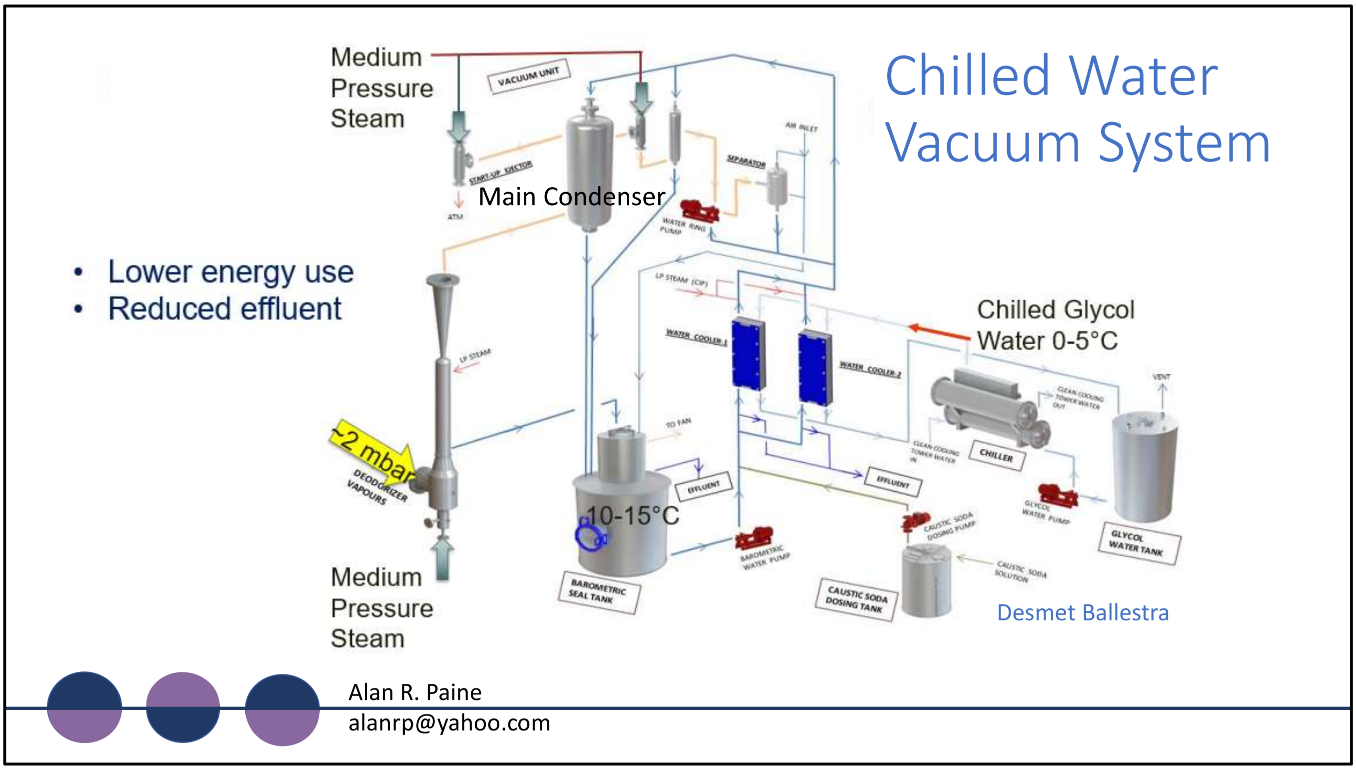
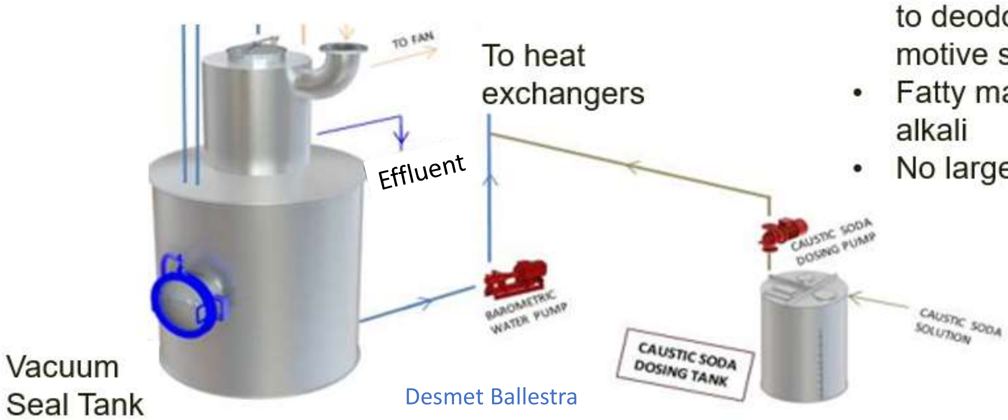
Cooling towers with their large fans are very effective at spreading odors over a wide area and it is often possible to smell a refinery kilometres away if it is using this type of system. The amount of land used by the skimming pond is often quite large and in some refineries is taking up space that could be used for more productive purposes. The large pumps required to circulate the water and the energy required by the fans only add to inefficiency of the system.



Using chilled water reduces the pressure in the main condenser which reduces the steam requirement for the ejectors by about 2/3. The condenser water circulates through plate heat exchangers where glycol water at 0 - 5°C cools the circulating water to 5 – 10°C. There are two heat exchangers for cooling the circulating water so that one can be cleaned while the other is in use. Some electricity is required to refrigerate the water but the energy required is small compared with the steam saved. Chilled water vacuum systems use standard packaged water chillers and plate heat exchangers so the extra capital cost compared with the traditional system is not very high and payback times of around a year are possible. So it's not only good for climate change but also good for the bottom line.

Chilled water - controlled effluent flow



- Continuous effluent flow equal to deodorizing steam plus motive steam
- Fatty matter emulsified by alkali
- No large settling pond

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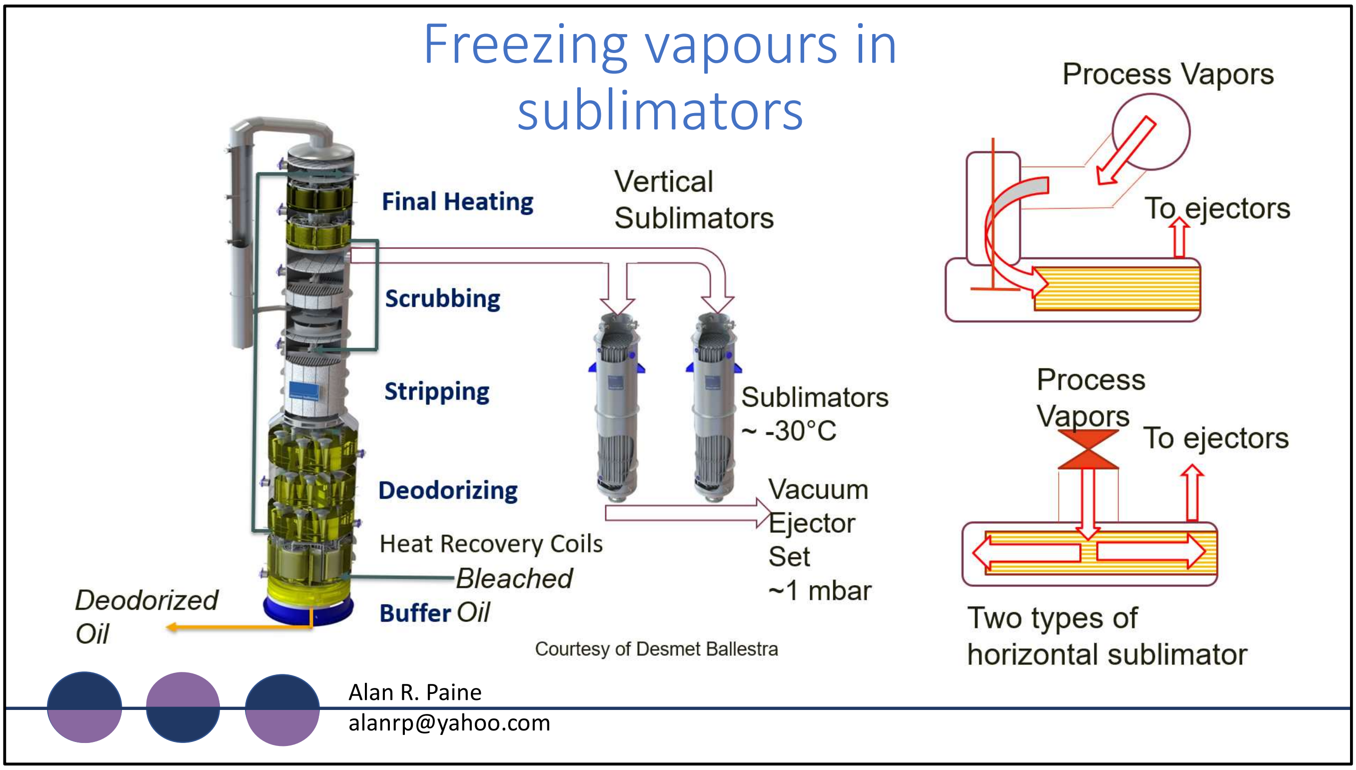
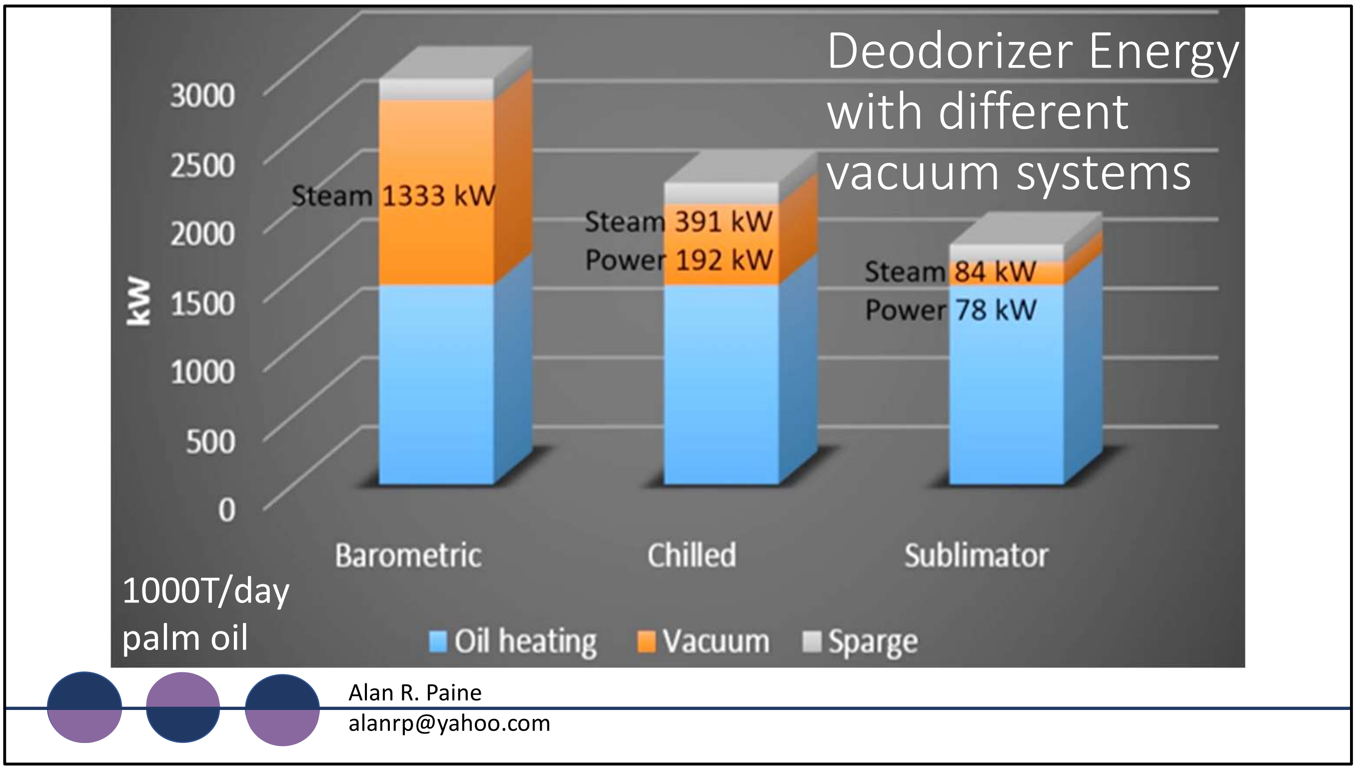
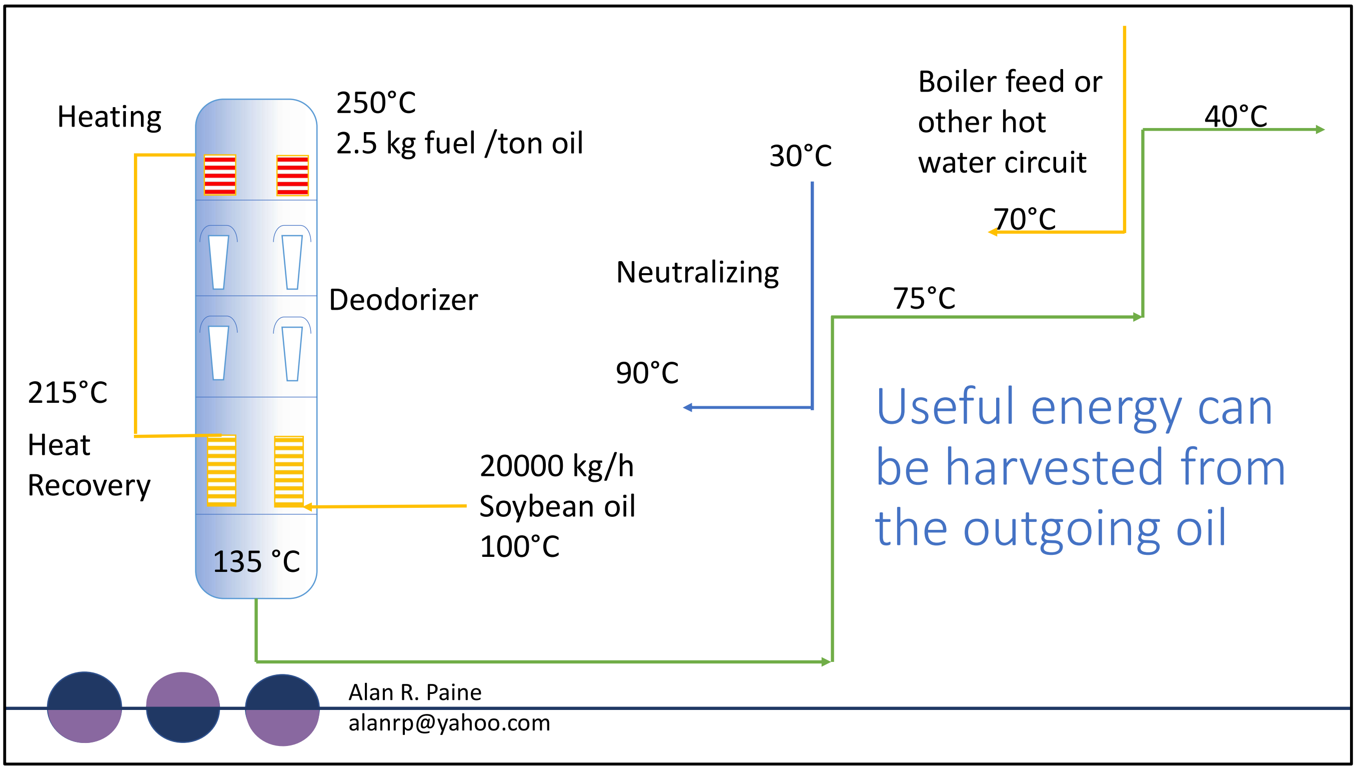
An additional benefit of chilled water vacuum systems is that the excess water which is slightly contaminated with fatty matter overflows continuously and is much easier to manage than recovering the fatty matter from a dirty water stream that is circulating through a cooling tower. The fatty matter is emulsified into the water using sodium or potassium hydroxide solution, the settling pond is no longer required, effluent costs are reduced and the smell is easily contained.



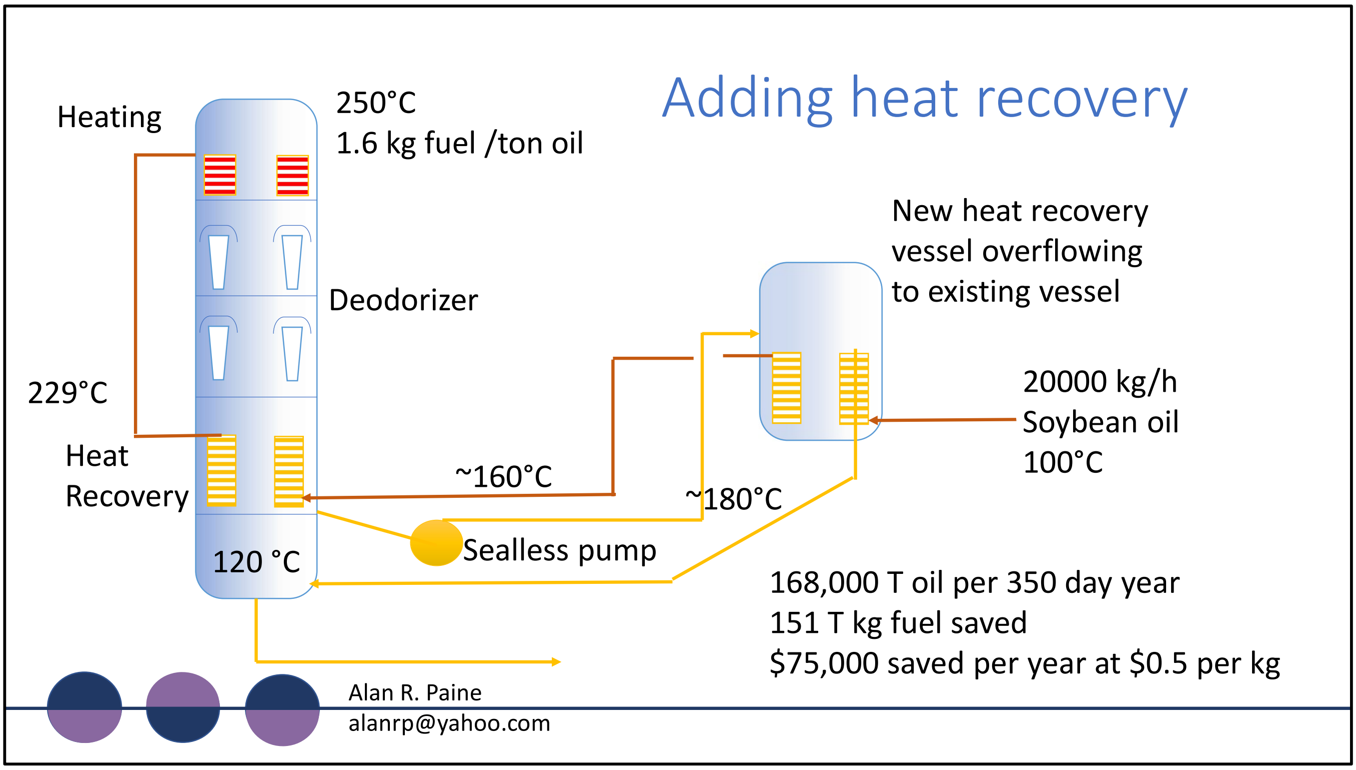
The steam requirement for the vacuum ejectors can be further reduced by freezing the vapor before it reaches the ejector set. The vapor passes through heat exchangers called sublimators or dry condensers which are cooled by liquid ammonia at about minus 30°C. Only a small amount of air and associated water vapor passes through. The steam consumption of the ejectors is much less than with other systems and although some electricity is required for the refrigeration the overall energy cost is well below other options unless steam is very cheap compared with the cost of electricity. There are several different sublimators designs available which can either be vertical or horizontal as shown in the picture.



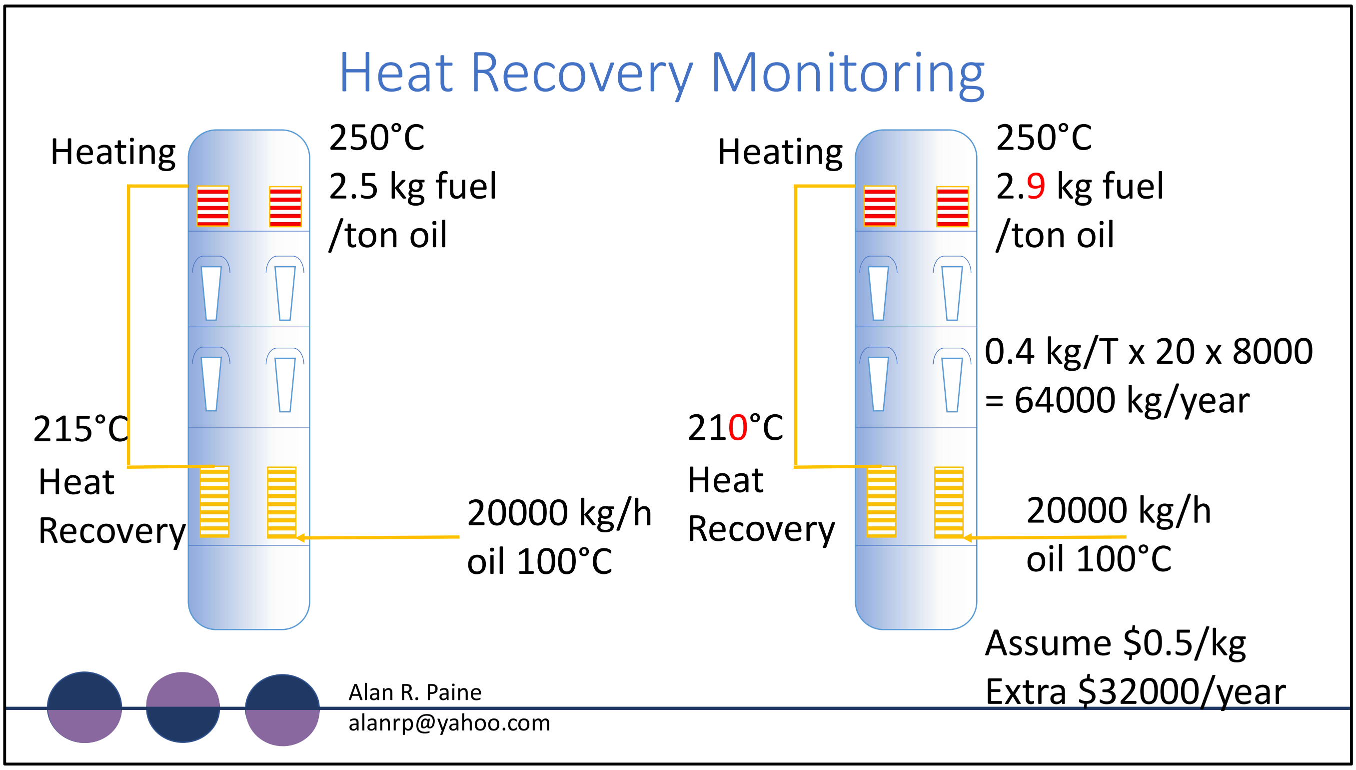
If we look at the overall energy consumption of a typical 1000 T/day palm oil deodorizer we can see that refrigerated vacuum systems use a lot less energy than the traditional 'barometric' arrangement and this doesn't take into account further savings in the cooling system. The orange bar shows the deodorizer injection steam energy, the steam used in the vacuum equipment and the electric power required for refrigeration. Chilled water systems use less than half the deodorizing and vacuum energy of the old system and the energy used by deodorizers with sublimators is only about 12% of the classic system. Sublimator systems are relatively expensive and can take some years to get a return on investment. They are not suitable for very small refineries but as the technology develops and energy becomes more expensive, as it probably will, then sublimators will become suitable for a wider range of situations.
Now while it has been possible to dramatically reduce the energy required for vacuum systems the heating energy represented by the blue bar has not been reduced to the same extent. When using sublimators the energy required for heating the oil is far more than the deodorizing and vacuum energy. In this example about 75% of the energy required to heat the incoming oil has been provided by the outgoing deodorized oil which sounds fairly good but it is still possible to do better.



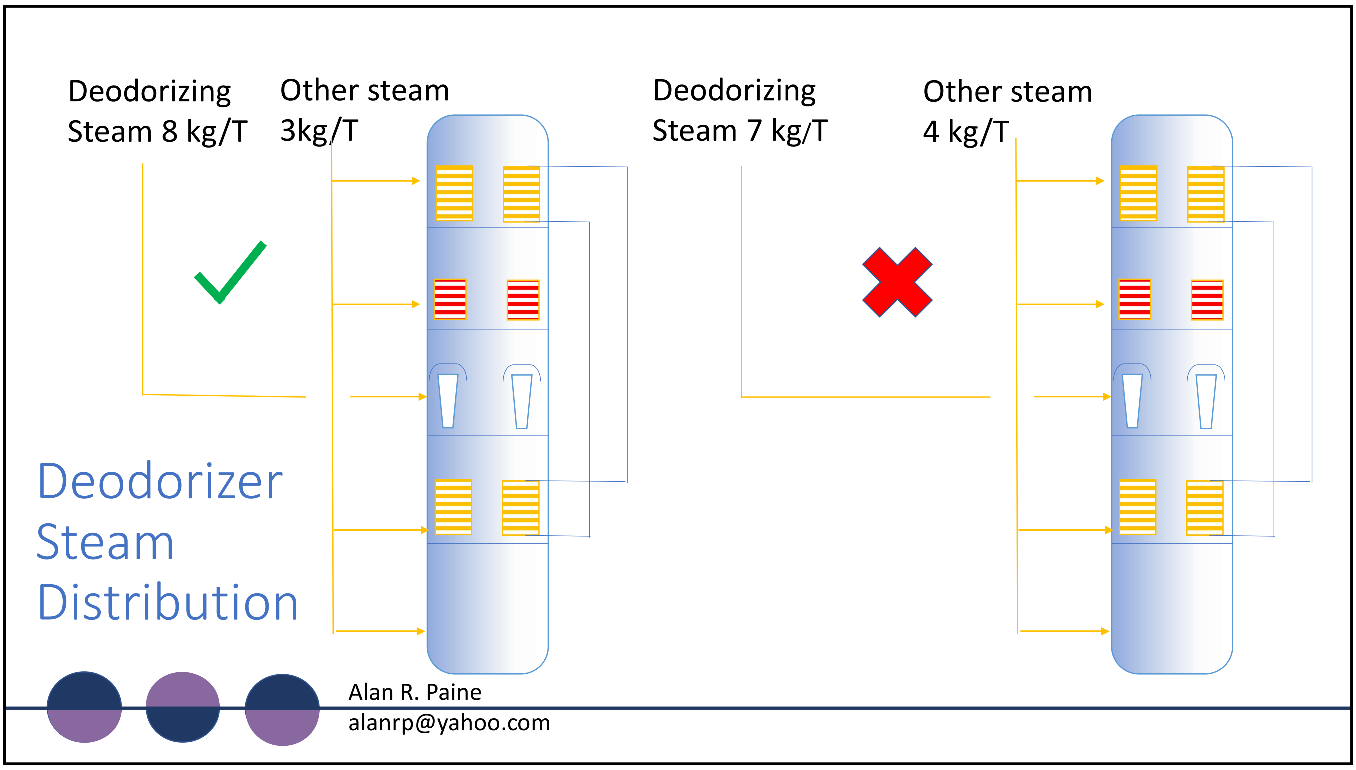
In this example soybean oil is heated from 100°C to 215°C by deodorized oil at 250°C. The rest of the heating is achieved using high pressure steam heated by 2.5 kg of fuel oil per tonne of soybean oil. The oil leaving the deodorizer is at 135°C and this can be used elsewhere in the refinery such as heating oil entering the neutralizing line or boiler feed water but in some refineries it is possible to generate more low grade heat than can be easily used and it can be difficult to exchange heat between different sections of a plant if they are not close to each other



One way to improve the heat recovery of the deodorizer and reduce the energy consumption of the high pressure steam boiler is to add an extra heat recovery vessel. There might not be room to install any additional equipment near the existing deodorizer but an additional heat recovery vessel can be installed in any convenient location if the oil is pumped to it using a sealless pump. In the example shown here the new vessel has the same heat transfer area as the existing deodorizer.
The fuel consumption is reduced from 2.5 to 1.6 kg fuel per tonne of oil and the outgoing oil at 120°C can still be used for low temperature heating if required. At a fuel cost if $0.50 per kg there will be a saving of $75000 per year. On this basis it would probably take a few years to payback the investment but after that maintenance costs would be very low and the savings would continue for many years.
If your current fuel consumption is a lot higher than 2.5 kg of fuel oil per tonne or about 3 Nm3 of natural gas per tonne then the energy saving could be a lot higher.



Even if you can't afford any new investment right now. It is still possible to save energy, reduce emissions and save money by monitoring the operation of existing equipment. A small change in the temperature profile of a deodorizer can have a large effect on the running cost. If oil is heated to 215°C in the heat recovery section of the deodorizer and then heated using light fuel oil to 250°C in the final heating section then this will require 2.5 kg of fuel per tonne of oil as we saw earlier. But if the bleached oil at the exit of the heat recovery falls to 210°C, which is only a small change in temperature and easy to overlook, then the fuel consumption rises to 2.9 kg per tonne which could cost over $30000 per year.



One more thing I'd like to say about deodorizer efficiency is that it important to measure the steam distribution correctly. Odours and other impurities are removed from the oil by bubbling steam through the oil at high temperature and low pressure. But a certain amount of steam is also required to agitate oil in parts of the deodorizer that are well below the deodorizing temperature. In heat transfer compartments we need agitation to get a good level of heat transfer but not much deodorization takes place here because the relatively low oil temperature.

The distribution of steam depends on the design. As an example on the left we have a deodorizer using 8 kg of steam per tonne of oil in the deodorizing compartments and 3 kg per tonne elsewhere in the vessel. But if the unit is not controlled properly and there are 4 kg per tonne of steam entering the non deodorizing compartments then we can only put 7 kg/T in the deodorizing trays which reduces the deodorizing capacity by 14%. The vacuum set continues to use the same amount of energy as before and the overall efficiency of the plant falls.

Renewable Energy

Wind

Solar

Biofuels

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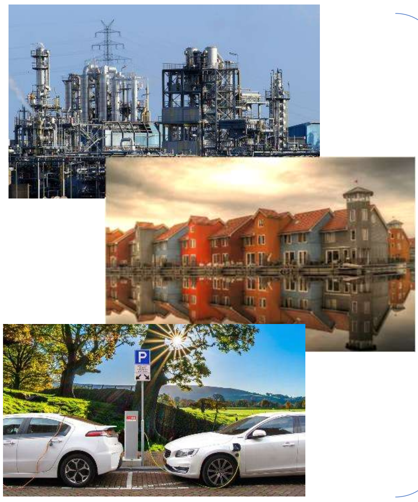
Images by pixabay

Renewable energy including wind, solar and fuels from biological sources have all been gaining popularity as ways of avoiding the release of greenhouse gases into the air. These methods are not necessarily totally carbon free: wind and solar farms have an energy cost for building them in the first place and if we are going to make fuel from agricultural products we have to make sure we are doing it with low greenhouse gas emissions. It’s no use cutting down a forest to create a fuel plantation and we have to make biofuels in a way that does not create fuel at the expense of essential food.

Fossil fuels easier to replace in some areas than others



Renewable electricity replacing fossil fuels

Liquid fuels hard to replace

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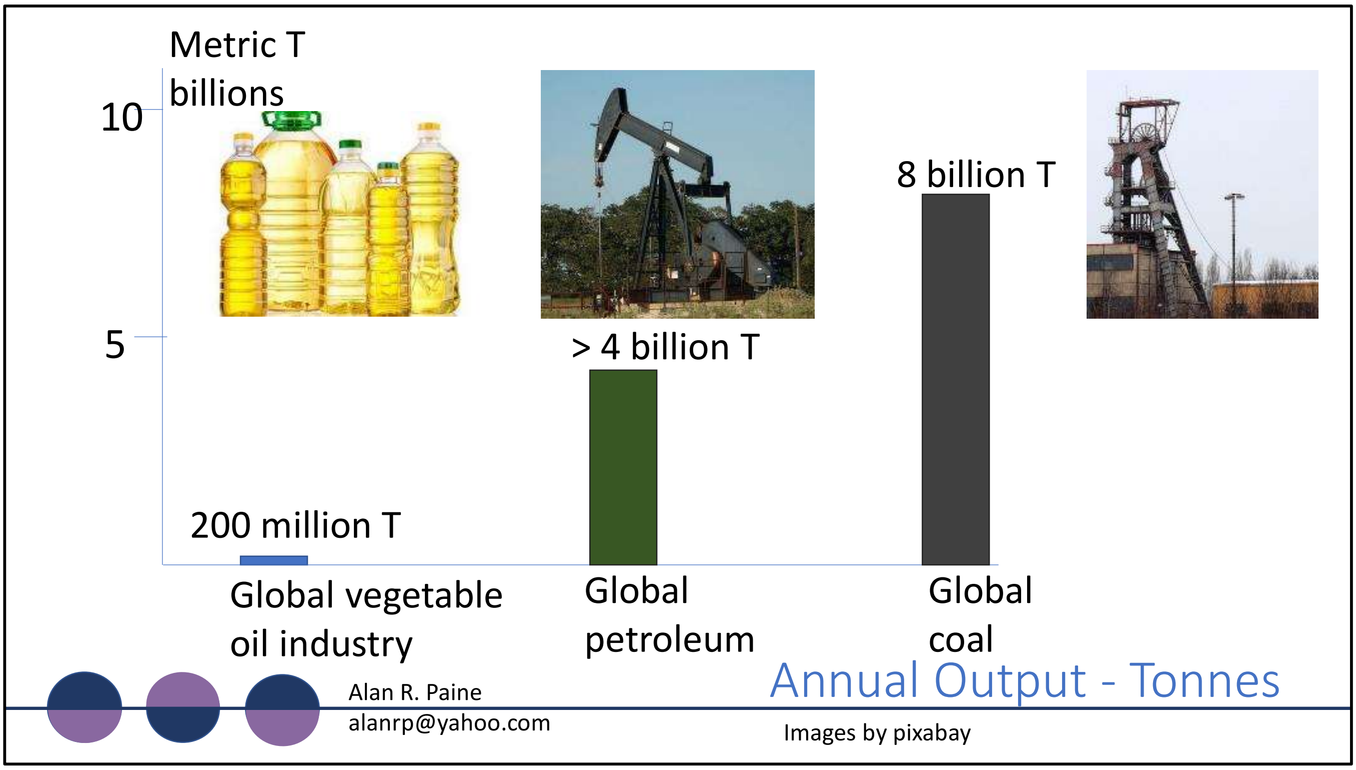
Images by pixabay

Low carbon energy from sources such as wind, solar, hydroelectric and nuclear can be used in industry homes and electric cars to replace fossil fuels and also to make hydrogen that can be used as a fuel but in the areas of freight transportation and air travel, hydrogen or electricity are impractical and we will probably still have to use fossil fuels or liquid fuels from renewable sources for some time to come.



Vegetable oil seems like an obvious choice to replace the oil that comes out of the ground but it’s not as easy as it first looks. The world production of vegetable oil is around 200 million tonnes per year and animal fats only add another 30 million tonnes per year but global petroleum production is over 4 billion tonnes per year and coal including lignite comes in at 8 billion tonnes

Heavy trucks air travel and shipping each use about 300 million T of fuel per year

Indexmundi, EIA

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Images by pixabay

Air travel in particular has taken a dramatic downturn in the past year but in a normal year uses about 300 million tonnes of fuel with heavy trucks and ships each using a similar amount. The use of vegetable oil to make industrial chemicals and plastics is also being proposed so it’s not hard to imagine at some time in the future a demand for fuels from biological sources exceeding a billion tonnes per year which is a very big number compared with what is now being achieved. Fortunately there are other ways to make these fuels in addition to growing more oilseed crops which will be covered in more detail at the AOCS meeting in May. But any way you look at it a future entirely free of fossil fuel use is going to be a challenge to reach.

Price of Oil

- **Petroleum ~$63/ barrel = $463/T**
- **Soybean oil ~ $1042/T**
- **Palm oil ~ $867/T**

indexmundi.com Feb 2021

Petroleum remaining at current usage – 50 years

https://ourworldindata.org

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The cost of petroleum is currently about $63/barrel which is nearly $500 per metric tonne. Vegetable oil on the hand costs about twice as much making it uneconomic to use as a fuel without subsidies and tax breaks. Of course the situation could change and current reserves of petroleum have been estimated by BP as being able to last about 50 years but I remember hearing in the seventies that petroleum production would peak around the year 2000 which didn't happen. There have been a few bumps in the curve but a steady downturn is yet to be seen and I wouldn't be surprised if over the next 50 years the presence of much more oil will be revealed.

Used Cooking Oil (UCO) is cheap but scarce

1.5 years of UCO from 2 people ~2 litres

European Biomass Industry Association

Potential supply in EU 8 litres/person (7 x the amount available in 2007)

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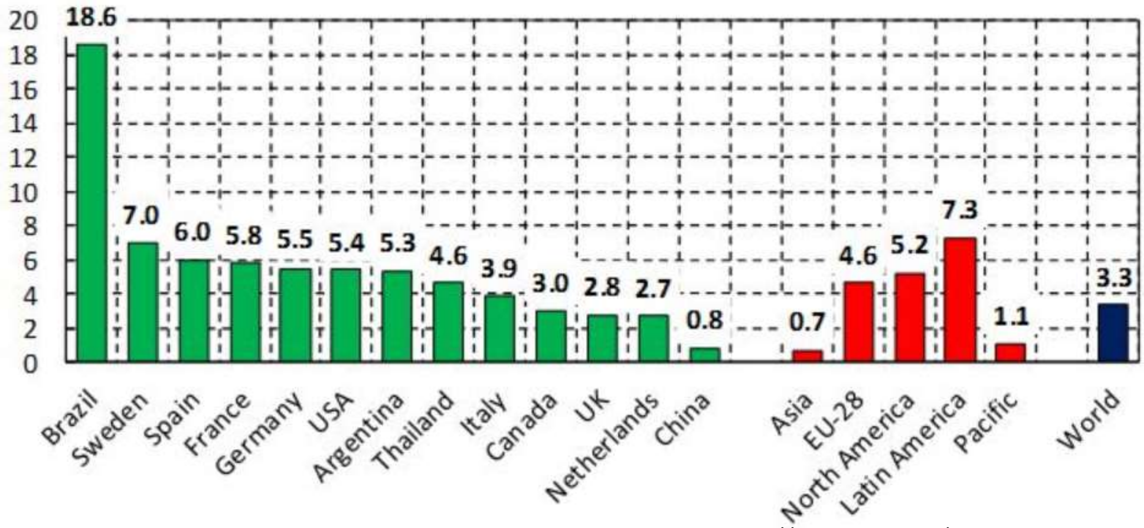
The biofuels industry has naturally turned to cheap sources of oil such as used cooking oil also known UCO. At home we have only managed to collect less than a litre per person over the past year and a half as shown in this plastic bottle which by itself won't get us very far. In the same period I have used around 1000 litres of diesel in my car. A study by the European Biomass Industry Association showed that the potential supply including restaurants and the food industry is about 8 litres per person/year in the EU but in 2007 only just over 1 litre per person/year was being recovered. More is coming onto the market but demand rising quicker than the supply and one of the consequences is that UCO is not only becoming more difficult to find it is also being adulterated with other low grade oils forcing the industry to have to work with oil that is very variable in quality and difficult to process.
We will look at ways to deal with the very poor quality of feedstock, that is often being seen these days, at the AOCS meeting in May.

Share of biofuels for road transport -2011



https://www.scielo.br/scielo.php?pid=S1980-993X2015000100009&script=sci_arttext

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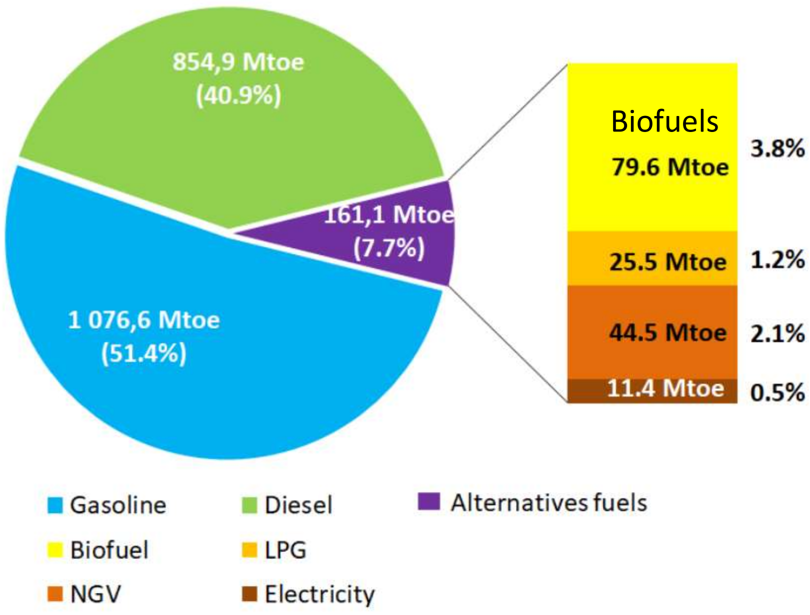
This chart shows how the share of biofuels for road transport varies in different countries. On a world level this was only 3.3% in 2011 and not only includes fuel made from natural oils and fats but also from sources such as corn and sugar cane.



Global energy road transport – millions of tonnes of oil equivalent. 2017

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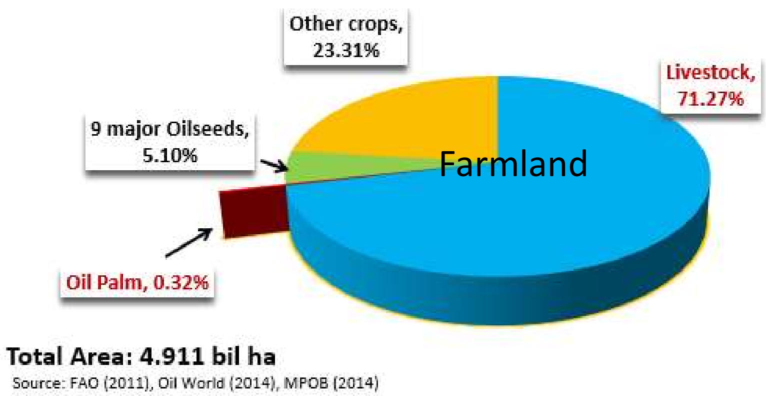
https://www.ifpenergiesnouvelles.com/article/biofuels-dashboard-2019

In 2017 the figure had risen to 3.8% and although this is not a big part of the total it is nearly 80 million tonnes of oil which is equivalent to a third of the global market in vegetable and animal oils and fats making it a significant industry.

Land use



Total Land 149 million km2
Including deserts, ice and other barren land

Habitable land 104 million km2

Farming	50%
Forest	37%
Shrub	11%
Built up	1%
Rivers, lakes	1%

Based on FAO 2019 figures

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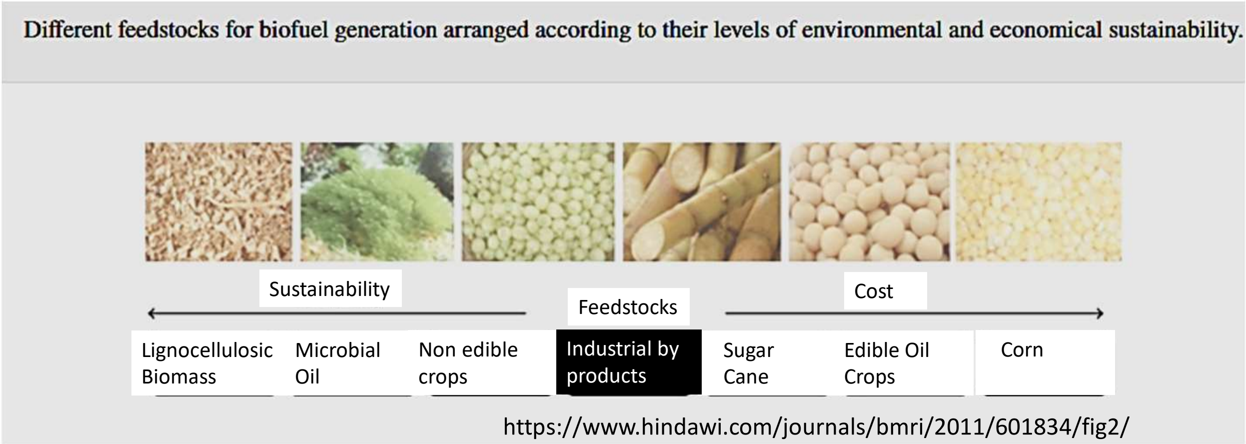
The amount of farmland in the world was 4.9 billion hectares or 49 million square kilometres in 2011. Palm oil manages to supply over a third of the world's vegetable oil using only 0.3% of agricultural land and all the other major oilseeds are only using 5% about half of which is planted with soybeans. Some campaigners give the impression that oil palms and soybeans are taking over world but in fact their global impact is not very great. Perhaps the most startling part of this chart is that over 70% of farmland is being used for raising animals including grazing and land for growing crops such as grain to feed the animals.

If we look at the wider picture the latest figures show that 50% of the world's habitable land is used for farming, 37% is forest and 11% is described as shrub some of which might be suitable for farming or re-forestation. Built up areas and inland water only account for about 1% each.

The population of the world is likely to rise by around 25% by 2050. It's theoretically possible to feed all those extra people and grow more oil crops for biofuels on existing farming land. Soybeans are a very efficient source of protein and if only a small part of the land that used to be tropical rain forest was used for growing palm oil then the amount of oil available for making biofuels would be increased by a very substantial amount. But in practice farming will most likely continue to put pressure on forests and other areas of natural vegetation. Farmers have to make a living like anyone else and can't just sit in the jungle living on fresh air.

Various sources of biofuel are available



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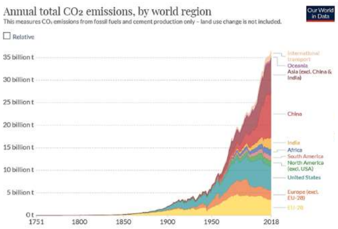
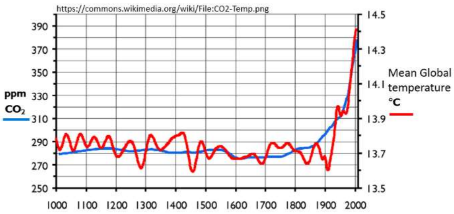
Fortunately there are a range of materials that can be turned into biofuels. Agricultural and forestry wastes and by products can provide what is known as lignocellulosic biomass. There are billons of tonnes per year of this stuff produced in the world each year although collecting enough into one place to process it can be a problem. Microbes, non edible crops grown on marginal land and industrial by products can add to the oil produced from edible material.
And in the AOCS May meeting we shall be covering alternative feedstocks including of the use of yeast found on rotting wood in the Chilean rainforest to produce biodiesel.

Summary

Air trapped in polar ice shows a strong link between atmospheric carbon dioxide and temperature





Increasing fossil fuel use has led to increasing carbon dioxide levels and increasing temperatures since the beginning of the 20th century

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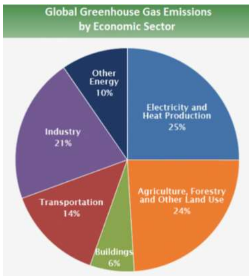
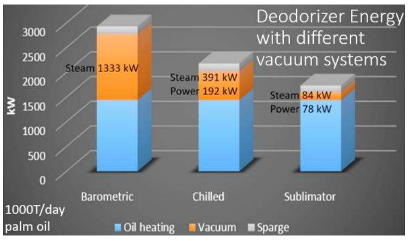
Summary 2





All parts of the economy are making significant contributions to greenhouse gas emissions so there is scope for making reductions in all areas of our lives

In vegetable oil processing large energy savings are often possible with a good return on investment and other industries have to do likewise.

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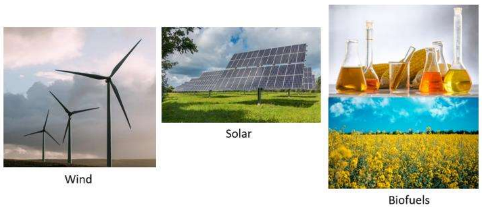
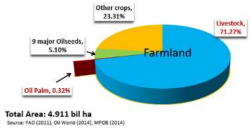
Summary 3

Renewable Energy



Land use



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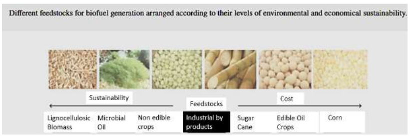

Renewable fuels including biofuels are increasing and will be a necessary part of reaching net zero carbon emissions by 2050

Rising populations will limit the amount of land that can be used for growing fuel crops

But new sources of biofuels are being developed which will be discussed in more detail at the AOCS on line meeting in May

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Thank you

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