It's the bioeconomy, stupid! An Introduction to the World of Bioenergy

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2013

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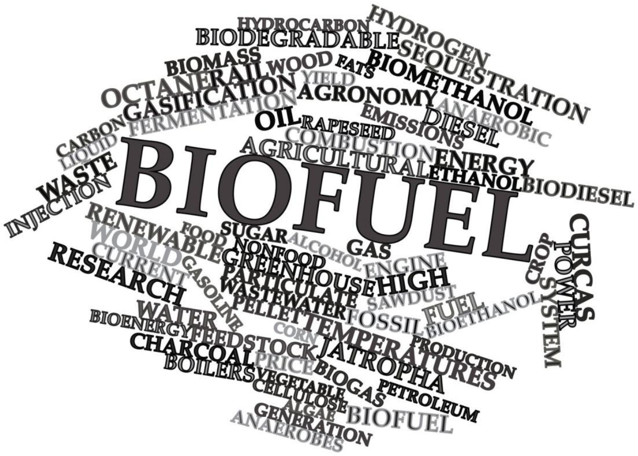

It's the bioeconomy, stupid!

AN INTRODUCTION TO THE WORLD OF BIOENERGY

Bioenergy is booming around the world and with the expansion comes exciting opportunities and some disturbing risks. Learning about bioenergy – from technologies, to resources, to policies – is important to the success and sustainability of the bioeconomy. This interactive guide for school students (16-18 years) and teachers opens the door to understanding and engaging in the transition from the fossil-based economy to a bio-based economy. Jump in!

Kes McCormick and Karin Willquist
May 2013

LU BIOFUELS

It´s the bioeconomy, stupid! An Introduction to the World of Bioenergy
By Kes McCormick and Karin Willquist

This guide has been developed with the support of LU Biofuels, which is a research platform that brings together researchers working on bioenergy and biofuels across faculties, departments and centres at Lund University in Sweden. Kes McCormick has been funded by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) to conduct research on the bioeconomy.

This guide is free of charge. Please distribute and provide comments by email (bioenergyschoolbook@lth.se). Thanks!

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INTRODUCTION

"It's the economy, stupid!" was a phrase widely used in the presidential campaign in the USA by Bill Clinton against George Bush in 1992. The phrase refers to the notion that Clinton was a better choice because Bush had not adequately addressed the economy, and it gets attention when you call people stupid. Now, in 2013, ***"It's the bioeconomy, stupid!"*** suggests that the opportunities, benefits and risks associated with the rapidly expanding bioeconomy, and particularly bioenergy, demand greater attention and scrutiny (see the biodictionary below).

Biodictionary: Some words to remember

The bioeconomy will be explained and explored throughout this guide. Put simply, a ***bioeconomy*** can be defined as an economy where the basic building blocks for materials, chemicals and energy are derived from renewable biological resources. But there are many other terms too. Biomass, bioenergy, biofuels are some common ones, and what about biotechnology and biorefineries? Sounds a bit complicated but in reality it is all rather straightforward. Furthermore, all of these terms make much more sense once you learn a little more about them and see a few pictures and charts.

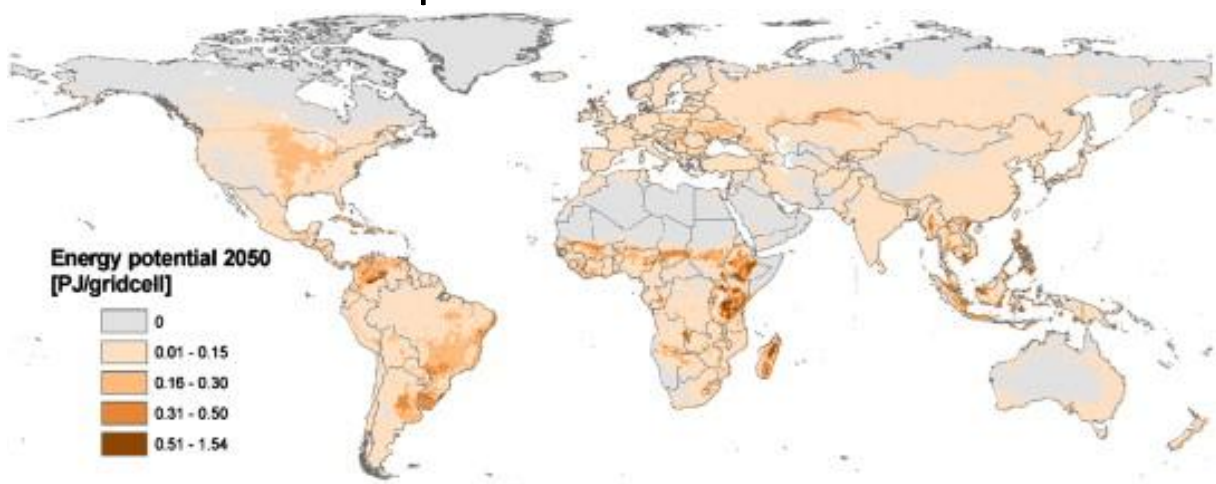
Humans exploit ***biomass*** (plant and animal matter) for many purposes. When it is utilized to produce heat, electricity or fuels for transport it is commonly called ***bioenergy***. Biomass can be considered as 'stored' solar energy because the process of photosynthesis 'captures' energy from the sun in growing plants. Utilizing biomass for energy purposes is in fact tapping into the vast energy available from the sun. In a broader perspective, ***bioenergy systems*** comprise both the technical aspects of bioenergy, such as conversion technologies and biomass resources, and the overarching non-technical aspects of bioenergy, such as policies and organisations.

The term ***biofuels*** is used in different ways. While it can refer to solid, liquid and gaseous fuels derived from biomass, it is also used to describe liquid (and gaseous) biofuels for transport. Biofuels are commonly categorised as follows: **first generation biofuels** are made from food crops, such as corn, wheat, sugar cane and oil seeds; **second generation biofuels** from non-food biomass, such as lignocellulosic materials, including cereal straw and maize stalks; and **third generation biofuels** from algae.

Biotechnology can be understood as the science of using living things to produce goods and services. It therefore involves manipulating and modifying organisms to create new and practical applications for agriculture, medicine and industry. ***Biorefineries*** offer the potential to better manage and capture value from biomass resources. Similar to petroleum refineries, which produce multiple fuels and products, biorefineries imply the integrated production of energy, fuels and chemical products from biomass.

The fast-emerging advanced bioeconomy represents a significant shift in socio-economic, agricultural, energy and technical systems. The bioeconomy is being made possible by the recent surge in scientific knowledge and technical competences that can be used to harness biological processes. Bioenergy and biofuels for transport are important outputs of the bioeconomy, but a range of bio-based products are expected to also underpin the growing bio-economy, including chemicals, plastics, food and feed, paper and pulp, and textiles. This shift or transition from the fossil-based economy to a bio-based economy is exciting and daunting, and it is occurring all over the world (see the biomap below).

Biomap: A few scenarios to check out



This picture shows the potential for bioenergy around the world in 2050. While the data and calculations behind this picture are very complicated, the message is that bioenergy can play a significant role in future energy systems (looking forwards to 2050), and it is developing countries and tropical regions where we can expect to see significant developments in biomass to energy, both for domestic use and international trade. It should be noticed that the potential for bioenergy in the future will depend on what we eat. If a majority of the population in the world will eat a lot of meat and a so-called rich diet, the potential for bioenergy is less than if we will base our diet on more vegetables and eat just what we need to survive.

As suggested, biomass takes many forms and can be converted readily into solid, liquid or gaseous fuels. For example, for each potato that you eat – as it is or as chips – the content of approximately one potato is just thrown away while it could contribute to the heating and powering of a household. This is just one example of the potential energy we waste. Think back on what you threw away yesterday, such as vegetables and fruit peels. It is easy to see that there is a large potential here. In fact, if all the annually produced household waste in Sweden would be collected and treated properly it could fuel all the communal bus fleet in Sweden with biogas for an entire year.

Most commonly, wood is chopped into chunks or chipped for ease of handling or even ‘pelletised’. Biomass can also be 'pyrolysed' or 'gasified' in specific ways to make liquids or gases. All forms of biomass can be burnt to raise heat (such as hot water or steam) or to produce electricity or both in a combined heat and power facility. Overall, direct combustion is the most common way of converting biomass to energy – both heat and electricity – and worldwide it already provides over 90% of the energy generated from biomass. It is well understood, relatively straightforward, commercially available, and can be regarded as a proven technology.

Like direct combustion, gasification is a high-temperature thermochemical conversion process, but the desired result in this case is the production of a combustible gas, instead of heat. This is achieved through the partial combustion of the biomass material in a restricted supply of air or oxygen. The product of gasification – containing hydrogen and called producer gas – can, after appropriate treatment, be burned directly for cooking or heat supply, or it can be used in secondary conversion technologies such as gas turbines and engines for producing electricity or mechanical work. Pyrolysis is thermal decomposition occurring in the absence of oxygen, and it is also the initial step in combustion and gasification processes where it is followed by total or partial oxidation of the primary products. The goal of pyrolysis is to produce a liquid fuel, termed bio-oil or pyrolysis oil, which can be used as a fuel for heating or power generation.

Some biomass is far too wet to be burnt successfully and so biological fermentation processes are used. Here, using containers that exclude air, biomass is 'digested' to produce a methane-rich gas called 'biogas' (see the exercise on building a biogas reactor) or fermented to produce hydrogen or alcohols such as ethanol or other specialised chemicals. The process of making ethanol is similar to the process of brewing bear. It is the same organism (yeast) that generally does the work (see the exercise on how to do a microbial fuel cell). Oil-rich biomass, such as rape seeds, sunflower, soy beans, jatropha and palm oil are very rich in energy and can be converted to biodiesel (see the exercise how to produce biodiesel). In contrast to biogas and bioethanol production, this is a chemical and not a biological process. It is also very important to keep in mind the efficiency of different fuels (see the exercise on measuring fuels efficiency).

The advantage of bioethanol and biodiesel is that they can be blended with gasoline and diesel, respectively, without any major complications. However, these fuels are associated with challenges such as, in some cases, increased food prices. This is since first generation bioethanol and biodiesel only use the edible part of plants and leave a great part of the energy in the plant to waste. Moreover, during the production of the biomass fertilisers are used, which both impacts food prices and greenhouse gas emissions. Another complex issue associated with biofuels and potentially affecting greenhouse gas emission is land use change. In short there are lots of issues to discuss (see the exercise on debating biofuels in a congress format) and measure (see the exercise on undertaking a life cycle analysis). Researchers active in bioenergy are often focusing on using alternatives to food crops as feedstock for biofuels production. These biofuels are often referred to as second generation or advanced biofuels.

Why read this guide?

Teaching more people about bioenergy is incredibly important to the success and sustainability of the bioeconomy. Young people in particular will play a key role in how the bioeconomy develops over time (see the biohistory below). LU Biofuels (which brings together researchers working on bioenergy at Lund University in Sweden) has therefore embarked on the challenge of producing a guide for school students (16-18 years) and their teachers about bioenergy developments around the world. The foundation for the guide is the expertise and knowledge of researchers engaged in LU Biofuels.

Biohistory: A quick look back over time

Since the 1990s, governments around the world (in both the North and the South) have been promoting bioenergy and biofuels based on concerns about climate change (especially in the EU) energy security (especially the USA) and rural and agricultural (in Brazil, but also in the USA and EU). Bioenergy has been promoted as a way to address climate change, improve energy security, and support rural development. Biofuels for transport are viewed as rather attractive because they can provide straightforward solutions to rising oil prices, as they can be distributed through existing infrastructure (pipelines, storage facilities, and fuel distribution networks) and existing technology and vehicles (namely internal combustion engines).

The major countries or regions that produce biofuels (Brazil, the USA and the EU) have enacted policies to support their development and helped create foundations for an emerging global industry. The EU and USA have set minimum mandates on the use of biofuels and provided a range of subsidies and research funding. In Brazil, there was significant support for biofuels in the 1970s and 1980s, which lessened in 1990s, but was revitalized in the 2000s. Agricultural lobbies (particularly corn in the USA and rapeseed in Germany), climate change activists and those seeking alternatives to fossil fuels, and government departments concerned with energy and security have provided a unique combination of interests for biofuels for transport.

But increasing food prices and the related food riots starting in 2006 and 2007 has dramatically altered the picture for biofuels. The production of biofuels has been pointed out as a cause of increasing food prices. However, estimates of the actual impact of biofuels production on total food price increases vary from 3% to 75%. In other words, there is a lot of disagreement. Doubts have also been raised about reductions in greenhouse gas emissions. Again, there is significant debate around biofuels and greenhouse gas emissions, but there appears to be some production chains that are much better than others. As a result of these debates, sustainability standards have been developed, particularly in the EU.

It is fair to say that for the biofuels and bioenergy industry these developments are a “window of opportunity” to focus on the promotion and development of biofuels and production chains that meet strict sustainability standards, and create many benefits from economic, social and environmental perspectives. New transformation processes of cellulosic material and waste, and the development of algae feedstocks are all exciting areas that offer avenues for improved biofuels. Another key challenge is to better involve and engage the general public, particularly young people, and key stakeholders, like farmers, in the shift towards biofuels. Sustainable biofuels is not just about technology, it is also about economic, political and organizational issues.

How to read this guide?

This guide contains six chapters on experiences with bioenergy in different places, including Sweden, Canada, Brazil, Australia, China, USA and Ethiopia. These countries are located across all the continents of the world. The chapters take an interactive approach to learning about bioenergy with maps, pictures, charts, cartoons, lab experiments, and discussion points (see the biohints below). The chapters contain information specific to the country in question but also information that puts bioenergy in broader perspectives. You do not need to read this guide from start to finish. Rather, just flip through, and see what jumps out at you. Read a bit, then chat with a friend, classmate or teacher. Learning usually starts with reading, thinking and talking! Finally, challenge your classmates by doing experiments and exercise at the end of the guide.

Biohints: Some things to keep in mind

Lies, damn lies and statistics! Always be careful when you look at statistics. You need to ask some questions about the numbers in front of you. You need to think about any gaps or how to interpret statistical information.

Everybody is entitled to their own opinion, but not their own facts! There are lots of opinions and debates about biofuels and bioenergy. Lively and transparent debate is good. But always look to the facts when making an argument.

The good, the bad and the future! As you read, you will see that for biofuels, there are clearly some production chains that produce lots of positive benefits, while others are not so good and should be altered. The future for biofuels is all about sustainability.

Technology will save us and the market is all powerful! There are many people that think technology and the market are the answer. But be aware that biofuels based on sustainable systems or production and consumption require strong policy and public engagement.

Further resources

In addition to reading this guide, check out another guide on bioenergy with lots of charts, maps and pictures entitled “Biofuels Vital Graphics” produced by GRID-Arendal and UNEP (visit http://www.grida.no/publications/vg/biofuels/). It visualizes the opportunities, the need for safeguards, and the options that help ensure sustainability of biofuels. Another great way to learn more about bioenergy is on the IEA Bioenergy educational website, simply called “About Bioenergy” (visit http://aboutbioenergy.info/). Both these resources can be combined with this guide to get a good picture of bioenergy, biofuels and the bioeconomy.

Comments please

It is important to view this guide as a living document. The world of bioenergy moves pretty fast, and the advanced bioeconomy is emerging right now. Things change, unexpected events happen and the near future might be quite different that we now believe. Teaching and learning about bioenergy is also a field that needs more development. The authors welcome comments and ideas on how to improve this guide! Please email (bioenergyschoolbook@lth.se) the authors, Kes McCormick and Karin Willquist (and let us know your thoughts for future editions. Thanks!

About the authors

Born in Australia, Dr. Kes McCormick has been living and working in Sweden for over 10 years. He completed his PhD on bioenergy systems in Europe focusing on social and political issues surrounding their implementation. He is very interested in how to better communicate bioenergy to the general public and key stakeholders. He is an active participant in LU Biofuels.

Dr. Karin Willquist was born in Sweden and performed her studies there and in Brazil, the Netherlands and Turkey. She is fascinated by biological processes and completed her PhD on biological hydrogen production. She has been involved in organising educational activities for LU Biofuels on bioenergy, biofuels for transport and the broader bioeconomy concept.

About LU Biofuels

LU Biofuels (visit http://www.lubiofuels.org/) is a research platform that brings together researchers working on bioenergy and biofuels from across faculties, departments and centres at Lund University in Sweden. We thank LU Biofuels for support and especially Gunnar Liden, Lovisa Björnsson, Mats Galbe, Linda Tufvesson and Marie-Francoise Gorwa-Grauslund for fruitful comments on the text.

LU
BIOFUELS

SWEDEN

Sweden is a world leader on the utilisation of bioenergy, particularly heat and power from biomass, but also biofuels for transport, including ethanol, biodiesel and biogas.

Sweden in Europe

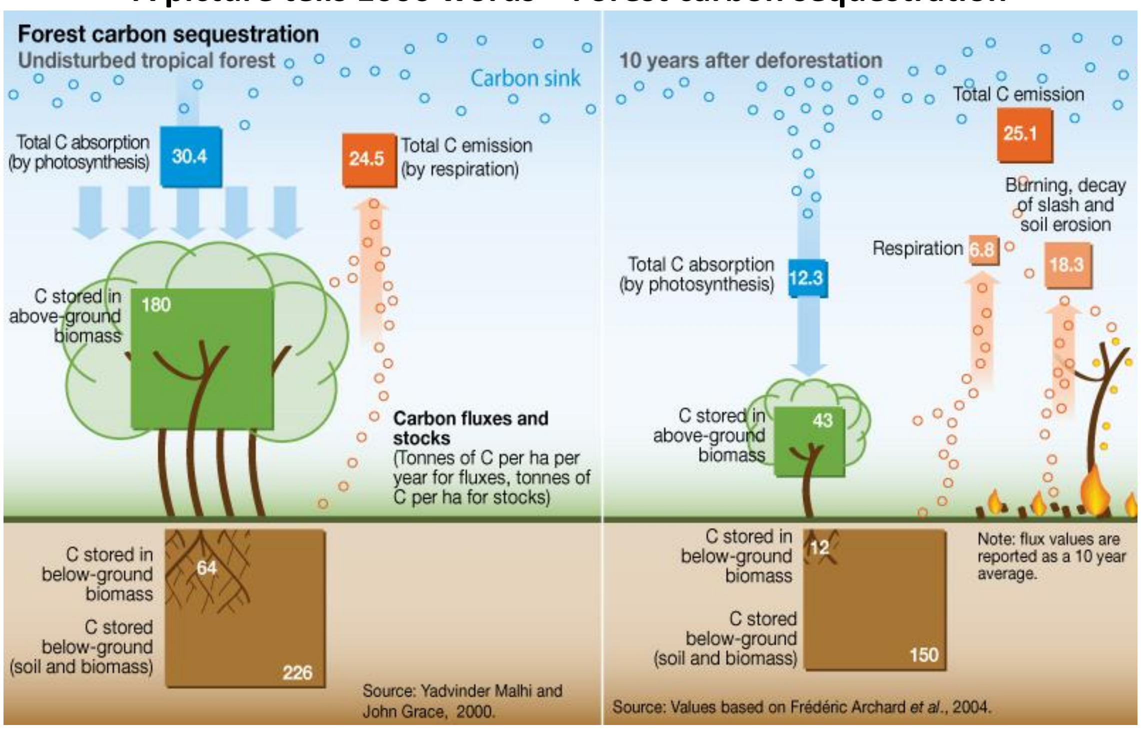
Surprising to many, Sweden is one of largest countries in Europe by area (at 450 thousand square kilometres). With a total population of about 9.4 million, Sweden has a low population density. About 85% of people live in urban areas, and Sweden's capital city is Stockholm. Sweden has considerable amounts of forest as well as pristine nature with mountains, lakes and rivers. It also has rich and fertile agricultural land.

National visions and actions

Sweden aims to become a low-carbon society and _break dependence on oil_ in the transport sector by 2030, which is an ambitious and exciting goal. What makes Sweden stand apart from many other countries is that it is actually working towards these goals with some success. The Swedish Government has aggressively shifted its energy system toward renewable energy, particularly bioenergy. Sweden has been able to develop heat and electricity based on biomass, and more recently Sweden has established biofuels for transport (especially ethanol, but also biogas) as a viable alternative to petrol and diesel. In short, over 2000 of the 4000 service stations in Sweden offer renewable fuels (particularly ethanol), flexi-fuel vehicles that can use high blends of ethanol (in Sweden this means 15% petrol mixed with 85% ethanol) are readily available as new and used cars, and over 10% of transport fuels in Sweden today are categorised as renewable fuels.

What does it mean to break dependence on oil? In 2006, the Swedish Government announced an impressive policy target – to create the conditions necessary to break dependence on oil and fossil fuels by 2020. This announcement attracted considerable attention from the world. The commitments to breaking dependence on oil have endured even though there has been a change in government. However, the timeframe has shifted to 2030 and the focus is on the transport sector. It is important to reflect on what this commitment means in reality. There will be oil in the transport sector in Sweden in 2030. However, the Swedish Government is working towards a situation where consumers will have "real" choice when purchasing vehicles and fuels, thereby breaking the complete dependence on oil that currently exists in the transport sector. What also makes the visionary plans in Sweden to break dependence on oil compelling is that Sweden has achieved considerable reductions in the use of oil since the 1970s. The announcements by the Swedish Government to shift away from oil, and promote renewable fuels (especially biofuels), is therefore a continuation of a national strategy.

A picture tells 1000 words – Forest carbon sequestration



A complex system is forest carbon sequestration. The picture above highlights that converting land for biofuels production can cause biodiversity impacts in the short-term, but it can also affect the future resilience of natural ecosystems. In an extreme case, complete deforestation reduces the ability of forestland to regenerate and absorb carbon long-term. The picture above shows how carbon is stored in biomass and the effects of deforestation. Sustainable biofuels demands that forests and land are managed intelligently and sustainably. Sweden provides an example where there are strong efforts to ensure sustainable forestry practices coupled with large-scale bioenergy production.

Who knows?

Founded in response to the oil crisis in the 1970s, the initial role of the ***International Energy Agency*** was to help countries coordinate a collective response to disruptions in oil supply. Over time the role of the International Energy Agency has broadened, and today it works to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The four main areas of focus for the International Energy Agency are energy security, economic development, environmental awareness, and engagement worldwide. The International Energy Agency gathers lots of data and information about all things energy, including renewable energy and bioenergy. It also develops scenarios and projections about the future to help decision-makers and governments around the world.

Check out http://www.iea.org/ for more information.

Discussion point: Biomass resources

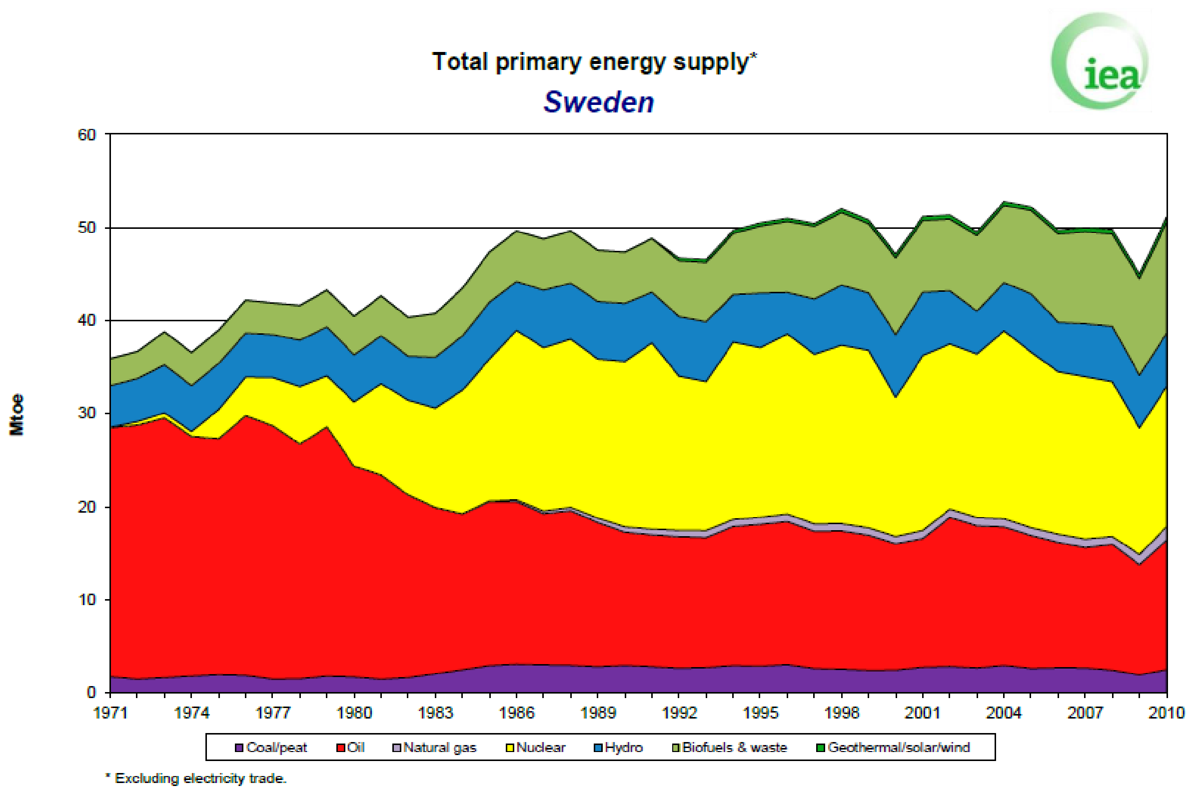
Biomass is a very broad term which is used to describe material of recent biological origin that can be utilised as a source of energy or for its chemical components. It includes trees, crops, algae and other plants, as well as agricultural and forest residues. It also includes many materials that are considered as wastes including food and drink manufacturing effluents, sludges, manures, industrial (organic) by-products and the organic fraction of household waste. Forest ecosystems are providers of environmental services to nature in general, but also as providers of a wealth of resources to humans in particular, including timber, biodiversity, and valuable carbon sinks, which help to remove carbon dioxide from the atmosphere. Furthermore, forests represent an energy resource which, if used in a sustainable and responsible manner, is renewable and practically neutral with regard to greenhouse gas emissions. Woody biomass of trees in forests can be converted into convenient solid, liquid or gaseous fuels to provide energy for industrial, commercial or domestic use.

Waste wood

Looking at agriculture, there is enormous potential for biomass resources for energy purposes, including growing crops dedicated for bioenergy as well as utilizing residues. However, there are many challenges to provide increasing amounts of food at the same time. Over last 30 years, the main cause of increased pressure on land resources has been food production. Agriculture will, in the future, have to face the task of feeding a growing human population, heading toward 10 billion people. Currently, many agricultural practices are not sustainable. For example, repeatedly growing crops on the same site requires the addition of large amounts of fertilisers to replace the nutrients lost from the soil and the use of pesticides (with the danger of increased pest resistance). Production of fertilisers can have negative effects on the environment with increased emission of gases that causes climate change. The practice of rapid destruction of natural ecosystems (such as forests) to provide land for agriculture can also cause the widespread extinction of plant and animal species (biodiversity). While there is considerable potential to utilize agriculture and forestry as a source of biomass, it is clearly critical to ensure strong sustainability standards.

Energy systems and sources

Based on IEA Energy Statistics, in 2010, biofuels and waste represented 23% of primary energy supply in Sweden. Coal, peat and natural gas provided only about 7% of energy supply. In fact, bioenergy in all its forms has been growing steadily in Sweden since the 1970s. In the electricity system, nuclear power and hydro power are dominant with renewable energy sources increasing. Biofuels for transport are expanding in Sweden rather rapidly and there are challenges to ensure that domestically produced biofuels and those that are imported meet sustainability standards.



The chart above shows the diversified mix of energy sources in Sweden and presents a few interesting points. First, coal and peat represented in dark purple, as well as natural gas in light purple, play a small role in energy supply. Second, oil in red has been decreasing since the 1970s.

Third, Sweden has nuclear power, depicted in yellow. Fourth, renewable energy sources, especially biofuels and waste in green and hydropower in blue, are significant and growing. Always remember, ***Total Primary Energy Supply (TPES)*** *means where we get our energy from in the first place, not like from the plug. In this chart, it shows different types of fossil fuels and renewable energy (including biofuels and waste). TPES is measured in this chart in* ***Millions of Tons of Oil Equivalent (MTOE)****. It is important to remember that final energy consumption is different to TPES as there are many energy losses before we can make use of energy services.*

In the news!

Europe tightens rules for biofuels use! In July 2011, the BBC reported that the European Commission has approved a number of certification schemes to ensure that biofuels used in Europe are produced in an environmentally and sustainable way. Companies producing or importing biofuels can either seek certification from one of these schemes or from a similar national scheme. The European Commission has made it clear that biofuels are a part of the strategy in Europe to reduce greenhouse gas emissions. Each scheme will verify where and how biofuels are produced. Biofuels grown on land that used to be forest or wetland will not qualify, and this is in direct response to key concerns raised over the production of biofuels in some parts of the world. A further major aspect of the certification schemes is that the standards will be tightened over time, so that biofuels will be forced to become more and more sustainable. This is will directly impact investments the development of more advanced biofuels.

Funny and true?

Yes, bioenergy can be used to power our appliances and electronic equipment, like televisions. But not quite as it is depicted above in the cartoon. We all know that burning wood produces heat, and this can be a way to heat homes with a fireplace or more efficiently with pellet heaters. But we can also burn or combust biomass in larger industrial facilities to produce heat and electricity at the same time. The electricity can then be distributed to homes and buildings through transmission lines, and the heat can often be utilised by industry or in some places, used *for heating homes or buildings through district heating systems, which involves heating water then pumping it underground in pipes. Overall, utilising biomass for energy is extremely versatile and very efficient when producing heat and electricity together.*

Sources

If you want to see where all the pictures, charts, photos, graphs, news and cartoons come from for this chapter on Sweden, check out the sources.

Item	Source	Link
Flag	CIA World Factbook	https://www.cia.gov/library/publications/the-world-factbook/geos/sw.html
Map	CIA World Factbook	https://www.cia.gov/library/publications/the-world-factbook/geos/sw.html
Chart – A picture tells 1000 words	Riccardo Pravettoni, UNEP/GRID-Arendal	http://www.grida.no/graphicslib/detail/forest-carbon-sequestration_06bd
Photo – Waste wood	Kes McCormick	
Graph – Total primary energy supply	IEA Energy Statistics	http://www.iea.org/stats/pdf_graphs/SETPES.pdf
News	BBC News	http://www.bbc.co.uk/news/world-europe-14205848
Cartoon	Cartoon Stock	http://www.cartoonstock.com/cartoonview.asp?catref=mfln31

CHINA

As a rapidly developing economy and a country with an enormous population, China is investing in many types of energy, including bioenergy in all its forms.

Today, China is the world's most populous country, with a population of over 1.3 billion people! Covering approximately 9.6 million square kilometres, China is also one of the world's largest countries by land area. The landscape in China is vast and diverse with forests, deserts and mountain ranges to name just some of the features. China’s capital city is Beijing, and its urban population is growing, as people move from rural regions into cities.

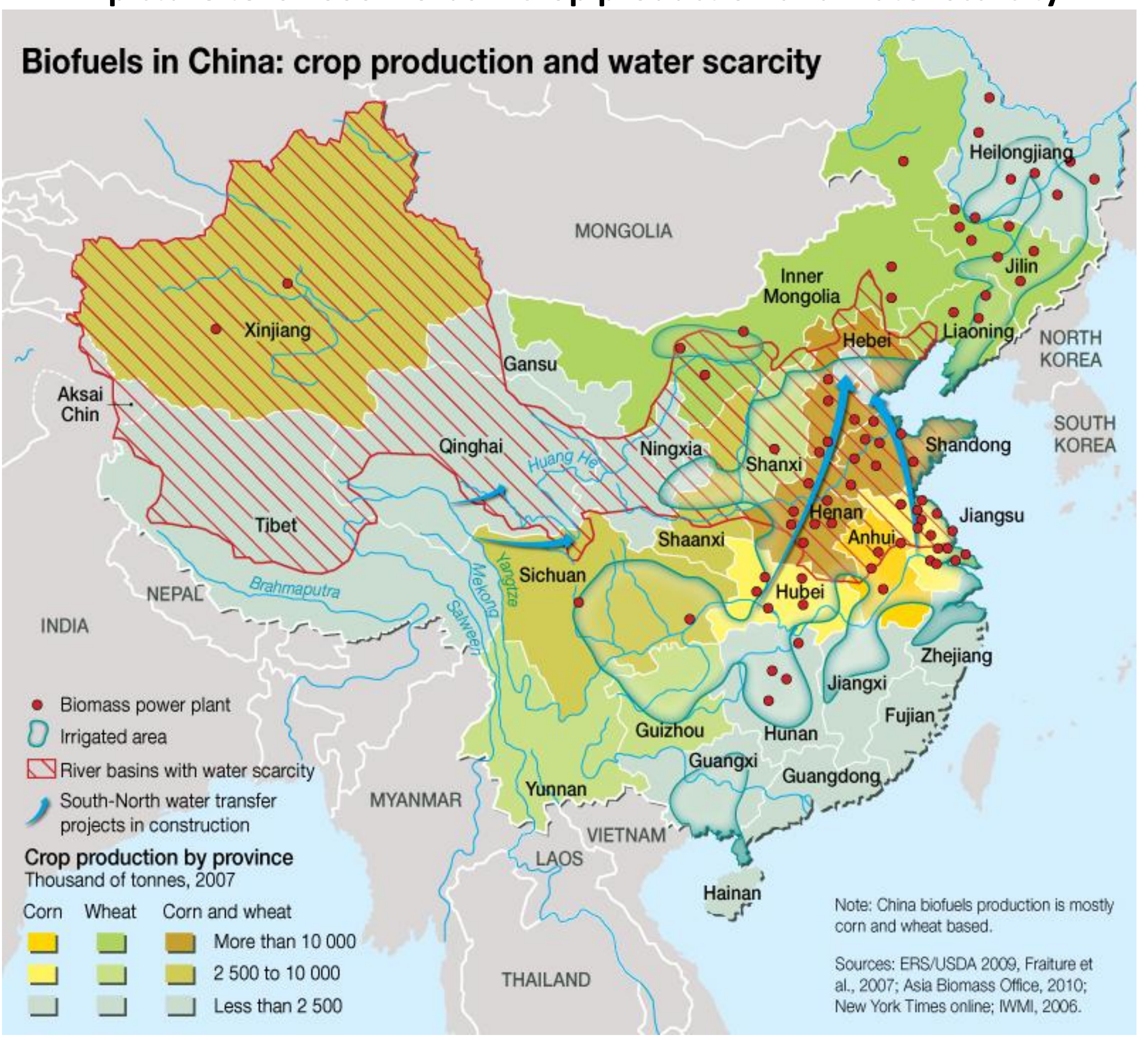
China in Asia

National visions and actions

With its enormous population and fast-developing economy, China is facing many complex challenges, including how to increase renewable energy. The Chinese Government is vigorously promoting the commercialization and implementation of renewable energy and bioenergy in the context of food, energy, and national security concerns. Goals include replacing 15% of conventional energy with renewable energy by 2020 and providing the necessary investment. The Chinese Government puts together *5 year plans* that define key goals and actions to be taken over 5 year periods. In these very important documents, expanding renewable energy is key item in future visions for China. Furthermore, China has already invested heavily into renewable energy and greater developments can be expected over the coming decades.

So what are 5 year plans? The 5 year plans developed in China are a series of social and economic development initiatives that started in the 1950s. These plans and visions play a leading role in establishing the foundations and principles of government in China, mapping strategies for social and economic development, setting growth targets, and launching reforms. China is now up to its 12th 5 year plan. In its latest plan, the emphasis is on rebalancing its economy, shifting focus from investment towards consumption and development as well as from urban and coastal areas toward rural and inland areas. The 12th 5 year plan also continues to advocate objectives to enhance environmental protection and develop renewable energy sources as well as "clean" vehicles. It is important to understand the 5 year plans in China when looking at bioenergy developments.

A picture tells 1000 words – Crop production and water scarcity



With China having 20% of the global population but only 7% of its arable area, biofuels production is clearly constrained by land availability. However, a far more precious resource may be the most limiting factor yet – water. There are concerns in China about the impact of mass cultivation of biofuels on water resources and quality. The picture above shows biomass power plants, irrigated areas and river basins with water scarcity as well as water transfer projects.

Who knows?

Founded in 2008, the ***World Bioenergy Association*** is the global organisation dedicated to supporting and representing the wide range of stakeholders in the bioenergy sector. Members include national and regional bioenergy organisations, institutions, companies and individuals. The main purpose of the World Bioenergy Association is to promote the utilisation of bioenergy globally in an efficient, sustainable, economic and environmentally friendly way. The World Bioenergy Association puts a strong emphasis on sustainability by addressing a number of pressing issues including certification, standardisation, and the debates about how bioenergy can impact on food, land use and water supply.

Check out http://www.worldbioenergy.org/ for more information.

Discussion point: International trade

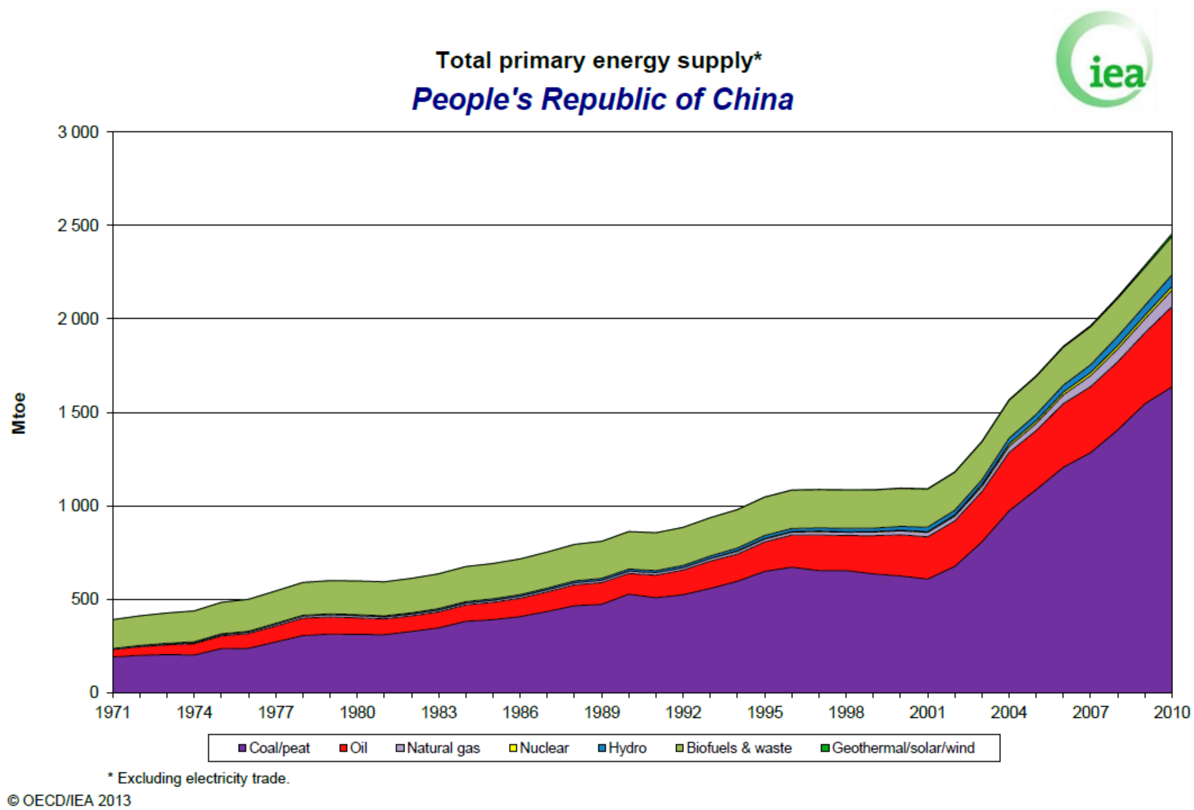
Currently, most bioenergy and biofuels production is consumed within countries. But international trade between countries around the world in biomass (as wood chips and pellets for example) and liquid biofuels is beginning to grow quickly, particularly because some industrialised countries lack the capacity to meet their growing domestic demands and some developing countries have excellent conditions for producing and exporting biofuels, like Brazil and Ethiopia. Although increased trade levels are expected to drive the development and deployment of new and innovative technologies, particularly advanced biofuels for transport, there remain strong concerns that unregulated trade will not maximise the positive contributions of biofuels or minimise the risks. There is considerable ongoing debate on the international trade of biofuels and bioenergy.

Wood chips

Concerns about the possible negative environmental and social impacts of biofuels have stimulated the development of a number of certification schemes and sustainability initiatives for biofuels. These include initiatives by trade organisations, civil society groups, and government bodies. However, it is very difficult to design, implement and monitor such sustainability schemes. On environmental issues, some of the key areas are land use change, water availability, food production, and biodiversity loss (all topics discussed in this guide). There are also very important social issues related to labour conditions for workers engaged in the bioenergy industry and impacts on local communities of bioenergy trade. As suggested, there are many positive benefits that can flow from the international trade of biofuels and biomass, it is just very important that positive outcomes are ensured and any negative impacts are minimized.

Energy systems and sources

Based on IEA Energy Statistics, in 2010, over 67% of primary energy supply in China was based on coal and peat. This is an enormous amount and it is growing as China expands its electricity production and supply to its population. It is fair to say that all forms of energy are expanding in China as the Chinese Government grapples with the immense task of developing an energy system that meets the development aspirations of the nation. As a fast-developing country this presents complex challenges. Biofuels and waste represented 9% of energy supply in 2010, and there are investments flowing into bioenergy and biofuels for transport. But again, a major issue for China is the sheer size of its population and resulting energy demands. Expanding bioenergy needs to be based on smart and sustainable systems, processes and technologies.



The above chart presents a fascinating and disturbing picture for China (and the world). First, we can see that energy demand and supply increases rapidly from the 2000s onwards. Second, the dominant source of energy is coal in dark purple. Third, biofuels and waste is a sizeable portion of energy supply in green. But overall, it is the significant coal use that is a problem both locally in terms of pollution and health impacts on people in China, and globally in terms of greenhouse gas emissions that cause climate change. Always remember, ***Total Primary Energy Supply (TPES)*** *means where we get our energy from in the first place, not like from the plug. In this* *chart, it shows different types of fossil fuels and renewable energy (including biofuels and waste). TPES is measured in this chart in **Millions of Tons of Oil Equivalent (MTOE)**. It is important to remember that final energy consumption is different to TPES as there are many energy losses before we can make use of energy services.*

In the news!

Seeing the forest for the trees. In December 2011, the BBC reported about the large mix of renewable energy technologies – many of them new and exciting. But among all these technological solutions is an energy source that humans have relied on for thousands of years and it is now being seen a key component in renewable energy production – it is the tree. Governments around the world are paying power stations to burn wood to generate electricity. It is possible to mix wood and coal in power stations. However, some environmental groups argue the push for burning more wood will increase deforestation hence affecting the carbon cycle and biodiversity. Another effect of using more wood for energy is that it can impact markets and the price of wood. Some argue that the demand for wood will greatly increase in the coming decades. This brings up an important debate about what parts of trees should be used for bioenergy and also what types of wood. It makes a lot of sense that once wood has been used, such as in buildings, that it can then be burned to produce energy (after a building has come to the end of its "life"). Since wood has many purposes, it is important for policy-makers to ensure that increasing bioenergy fits into other markets and uses for wood.

Funny and true?

"IT'S A VOLKSVEGAN...IT RUNS ON VEGETABLE OIL!"

The cartoon above suggests that cars can now be vegans or vegetarians, which in some ways they can be based on using biofuels. The most common fuels available today are ethanol, biodiesel and biogas. Ethanol and biodiesel are liquid fuels and can be used in existing vehicles *with some modifications. Flexi-fuel cars can use high blends of ethanol, such as 15% petrol with 85% ethanol. Ethanol is being increasingly blended with all petrol at 5% or 10% levels, and this can be used in all conventional vehicles with no changes. Biogas as the name suggests is a gaseous fuel that requires a special tank to store the gas. Bi-fuel cars can use both petrol and biogas as they have a tank for each fuel.*

Sources

If you want to see where all the pictures, charts, photos, graphs, news and cartoons come from for this chapter on China, check out the sources.

Item	Source	Link
Flag	CIA World Factbook	https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html
Map	CIA World Factbook	https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html
Chart – A picture tells 1000 words	Riccardo Pravettoni, UNEP/GRID-Arendal	http://www.grida.no/graphicslib/detail/biofuels-in-china-crop-production-and-water-scarcity_defb
Photo – Wood chips	Kes McCormick	
Graph – Total primary energy supply	IEA Energy Statistics	http://www.iea.org/stats/pdf_graphs/CNTPES.pdf
News	BBC News	http://www.bbc.co.uk/news/business-15756074
Cartoon	Cartoon Stock	http://www.cartoonstock.com/cartoonview.asp?catref=bfrn142

BRAZIL

Brazil has transformed its transport sector with the introduction of ethanol from sugarcane. It is a major player in the global development of bioenergy and the international trade of biofuels.

Brazil is the largest country in South America, and one of the world's largest countries, by geographical area (at over 8.5 million square kilometres) and by population with over 192 million people. Brazil is famous for the tropical rainforests of the Amazon. The capital city of Brazil is Brasilia. There are many large cities in Brazil and over 80% of the population lives in urban areas.

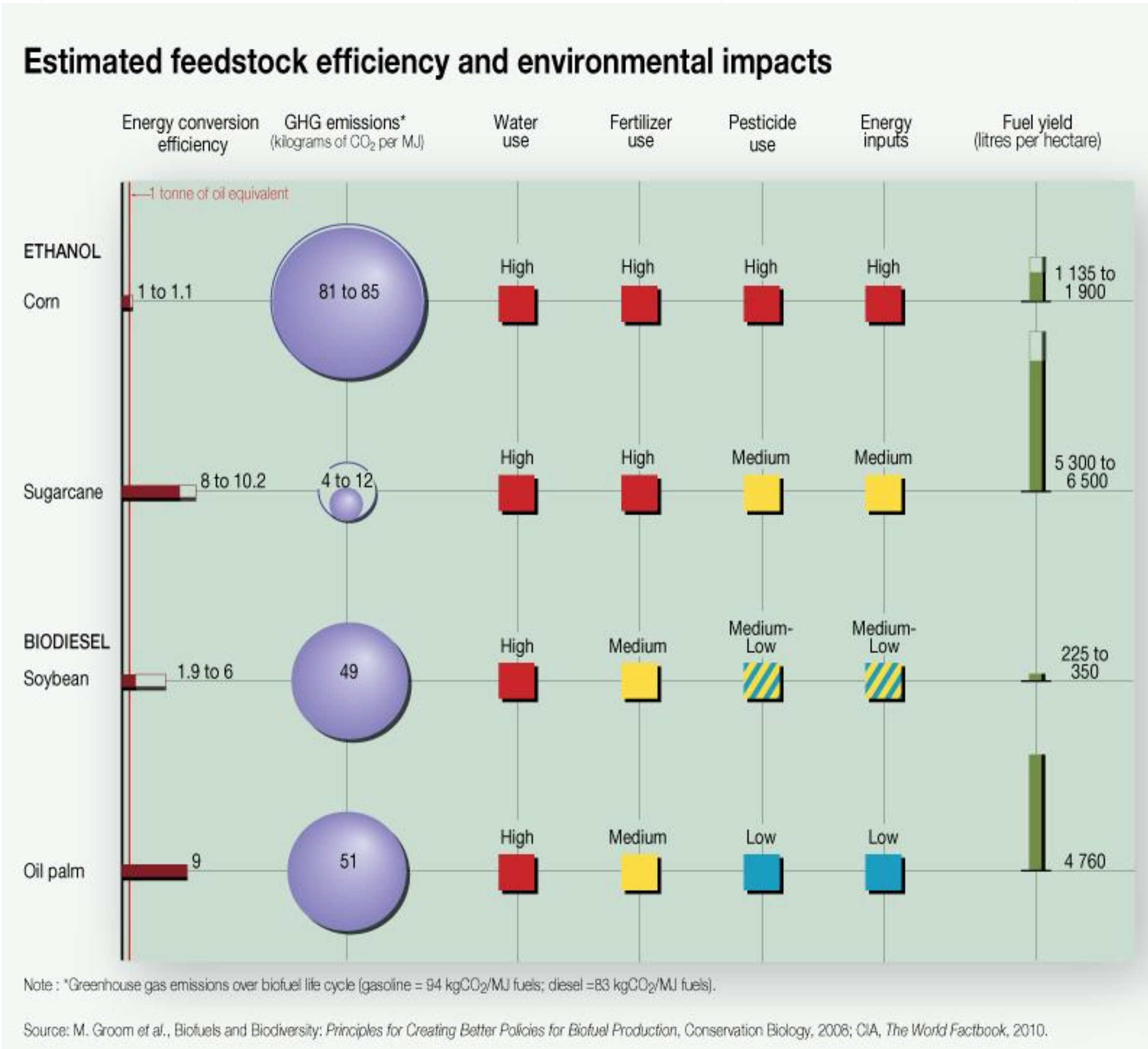
Brazil in South America

National visions and actions

Brazil has been a pioneer in bioenergy and biofuels since the 1970s when it embarked on an ambitious ethanol and sugar production strategy, called the *National Alcohol Programme*. Today, Brazil is a major global player in the trade of biofuels and technologies. The Brazilian Government has provided significant support for the development of bioenergy over several decades and this has created a vibrant industry in Brazil around ethanol and sugar. Clearly, there are visions in Brazil to take full advantage of this situation, particularly through increasing trade in biofuels but also technologies, systems and know-how.

So tell me more about the National Alcohol Programme? The National Alcohol Program was launched in 1975 as a nation-wide programme financed by the Brazilian Government to phase out automobile fuels derived from fossil fuels, such as petrol, in favour of ethanol produced from sugarcane. The Brazilian Government made the blending of ethanol fuel with petrol mandatory and this significantly stimulated the market for the production of biofuels and the flexi-fuel vehicles that can use ethanol blended with petrol. This in turn resulted in service stations selling ethanol, so Brazil was able to get the three pillars of biofuels in place simultaneously – the production of biofuels, the availability of biofuels at service stations, and the flexi-fuel vehicles into the marketplace.

A picture tells 1000 words – Feedstock efficiency and environmental impacts



A very important issue for the production of biofuels for transport is the efficiency of the production processes and environmental impacts. The picture above compares ethanol and biodiesel based on different feedstocks. Brazil produces large amounts of ethanol from sugarcane. Take a look and see what the picture tells you about water use, greenhouse gas emissions and a number of other key factors.

Discussion point: Ecological systems

Managing and using biomass can deliver substantial benefits in terms of increased biodiversity, local amenity and even rehabilitation of land and water courses. However, at the same time expanding the use of biomass for energy can have negative impacts on ecological systems. It is therefore paramount that bioenergy systems are designed and implemented with ecological systems in mind. For example, the loss of biodiversity can occur as a result of many human activities, including land conversion, climate change, pollution and unsustainable harvesting of natural resources. The extent to which an ecosystem has a few or many different species and types of organisms is termed its biodiversity. Ecosystems with a greater diversity are often thought to be more healthy and robust. It is not an overstatement to say that human health and well-being are directly dependent on biodiversity.

Agricultural biomass

Another example that is very relevant to bioenergy is soil fertility, as soil forms an integral part of the environment. All plants depend on it as a reserve of nutrients for a healthy functioning, thus making soil essential for the production of food and other crops, but also for maintaining biodiversity and for the landscape. Bioenergy production, both from energy crops and from forest and agricultural residues, can affect the naturally balanced nutrient cycles leading to degradation of soil fertility. Removing nutrients when biomass feedstock is harvested from the field, especially in the case of rapid-growth bioenergy crops and complete removal of agricultural residues, ultimately interrupts the natural process by which decomposing plant matter would replenish soil nutrients and effectively makes the soil less fertile. Impacts on biodiversity and soil are important factors to investigate with bioenergy developments.

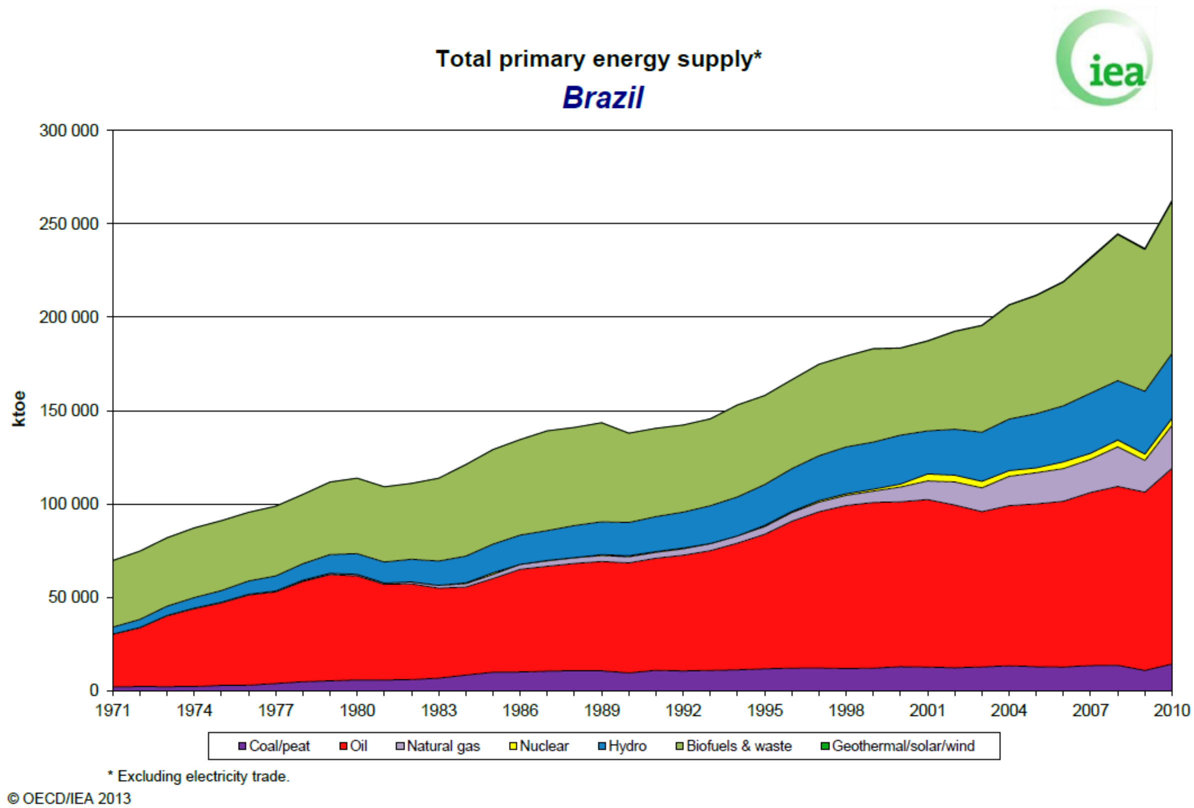
Who knows?

Since 1971, ***Greenpeace*** has been campaigning against environmental degradation. Greenpeace has been engaged in many significant environmental, climate and sustainability campaigns. Greenpeace argues that it exists because the Earth needs a voice, it needs solutions, it needs change and it needs action. Currently, key focus areas for Greenpeace include climate change, forests, oceans, agriculture, toxic pollution and nuclear power. Greenpeace have raised concerns about increasing bioenergy utilization, and called for strict environmental controls to avoid negative impacts, such as deforestation affecting the carbon cycle and the biodiversity. Most importantly, Greenpeace argue that only biofuels that can significantly reduce greenhouse gas emissions should be supported.

Check out http://www.greenpeace.org/ for more information.

Energy systems and sources

Based on IEA Energy Statistics, in 2010, over 40% of primary energy supply in Brazil was based on oil, while biofuels and waste represented 32% (which is very large indeed). Coal, peat and natural gas together were only 11% and hydropower was some 14%. However, in terms of the electricity system, hydropower is the dominant source. Biofuels for transport are also well-established and provide a viable alternative to petrol and diesel. In fact, the production of biofuels in Brazil is so significant that it is major player in international trade, especially for ethanol.



The above chart tells us many things about energy in Brazil. First, we can see that the primary energy supply has increased steadily since the 1970s with a slight dip in 2008. Second, renewable energy sources play a major role in the energy system with biofuels and waste in green and hydropower in blue. In fact, bioenergy has been and remains an integral part of energy supply in Brazil. Third, there remains a significant dependence on oil, which is depicted in red. Always remember, ***Total Primary Energy Supply (TPES)*** *means where we get our energy from in the first place, not like from the plug. In this chart, it shows different types of fossil fuels and renewable energy (including biofuels and waste). TPES is measured in this chart in* ***Millions of Tons of Oil Equivalent (MTOE)****. It is important to remember that final energy consumption is different to TPES as there are many energy losses before we can make use of energy services.*

In the news!

Is bioenergy fuelling the food crisis? In June 2008, the BBC reported on the biofuels debate and increasing food prices, stating that bioenergy and biofuels once hailed as a great solution to many challenges could be transformed into a “villain” because of impacts on food markets around the world. Some people and organisations argue that subsides for producing biofuels mean that land is being diverted away from food production. While it is clear biofuels have some effect on food markets, the significance is debated from very small to major negative impacts. The large nations involved in biofuels production and use at present include the USA and Brazil. But the development of biofuels in these places is very different, especially between the USA and Brazil. In the USA, the production of corn-based ethanol is heavily criticised as requiring energy and fertiliser inputs, resulting in limited reductions in greenhouse gas emissions, and directly impacting food markets. In contrast, sugarcane-based ethanol (such as in Brazil) is considered by many as a better developed market where positive impacts outweigh negative ones. However, there is still debate on land use change impacts in Brazil.

Funny and true?

The cartoon above brings up at least two important points about biofuels. First, they tend to smell nice or at least better than petrol or diesel. This is because they are based on plants in many cases. Second, the airline industry is investing into the development of aviation biofuels, and we can expect to see significant steps forwards in the near future. This is due to the fact that airlines are very sensitive to fuel prices, and as the cost of fossil fuels goes up, this will be a real problem. So alternative fuels, like biofuels, offer the airline industry a way to control fuel prices and at the same time become more sustainable and reduce greenhouse gas emissions. As the airline industry continues to grow, it is also very important that fuels can be less-greenhouse intensive, and biofuels can fulfil this requirement as well.

Sources

If you want to see where all the pictures, charts, photos, graphs, news and cartoons come from for this chapter on Brazil, check out the sources.

Item	Source	Link
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Chart – A picture tells 1000 words	Nieves Lopez Izquierdo, UNEP/GRID-Arendal	http://www.grida.no/graphicslib/detail/estimated-feedstock-efficiency-and-environmental-impacts_1eea
Photo – Agricultural biomass	Lennart Pettersson	
Graph – Total primary energy supply	IEA Energy Statistics	http://www.iea.org/stats/pdf_graphs/BRTPES.pdf
News	BBC News	http://news.bbc.co.uk/2/hi/europe/7435439.stm
Cartoon	Cartoon Stock	http://www.cartoonstock.com/cartoonview.asp?catref=dbrn608

USA

There are many challenges facing the USA on energy, especially its dependence on oil for transport. As a response, bioenergy is growing fast with investments from the public and private sectors.

At 9.8 million square kilometres and with over 314 million people, the USA is one of largest countries in the world. It is also perhaps the world's most ethnically diverse and multicultural nations. The environment and landscape is varied, and there are very many large cities in the USA. The capital city is Washington, and over 80% of people live in urban areas.

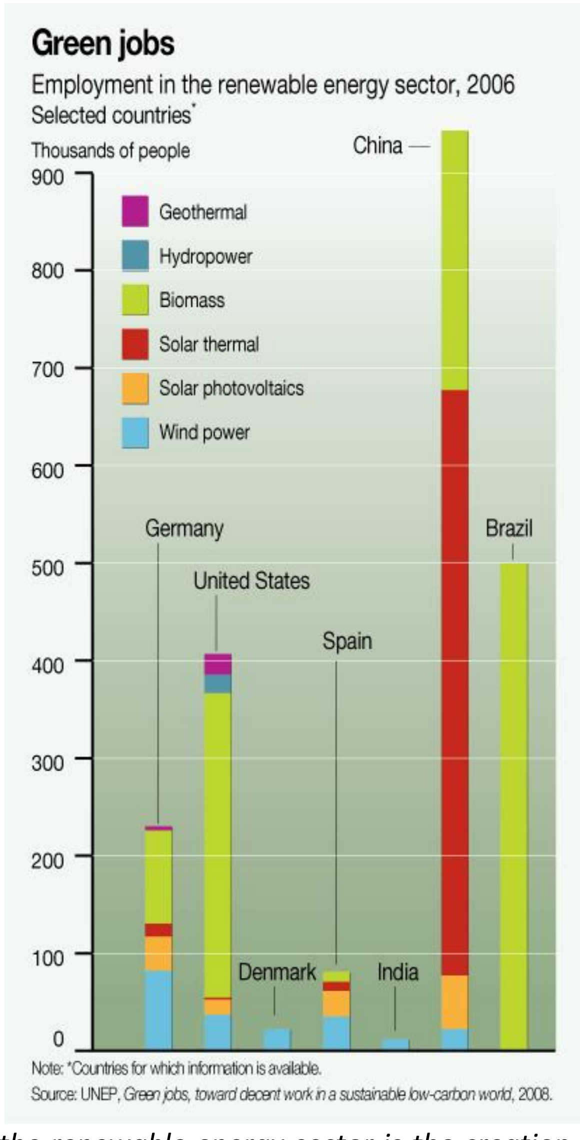
USA in North America

National visions and actions

A major concern in the USA is its dependence on fossil fuels, particularly oil. In this context, the President of the USA has outlined a goal of reducing oil imports to the USA by at least 30% by 2025, with increased support for technologies that can assist in such a transition, including advanced biofuels. It is energy security that is very high on the agenda for the USA and biofuels are considered a core part of breaking dependence on oil. However, the challenges for the USA are considerable because of its large population and heavy dependence on cars running on petrol and diesel. Turning its visions into reality will demand a long-term, concerted effort. The President of the USA has depicted how to do it in a *Blueprint for a Secure Energy Future*, which is perhaps the most comprehensive energy planning the USA has even seen.

But what is Blueprint for a Secure Energy Future? The President of the USA has set a goal of reducing oil imports by more than 30% by 2025 and laid out a strategy to develop domestic oil and gas resources, increase energy efficiency, and speed up the development of biofuels and other alternatives. At the same time the USA continues to take additional steps to reduce reliance on foreign oil. As part of that effort, the Blueprint for a Secure Energy Future directed the armed forces, department of agriculture and department of energy to collaborate to support commercialization of advanced biofuels. A key message is that biofuels can help improve the energy security of the USA, meet the energy needs of the armed forces, as well as the commercial aviation and shipping sectors. Overall, the Blueprint for a Secure Energy Future points to the serious concerns in the USA about energy security, and the role biofuels can play in breaking dependence on oil.

A picture tells 1000 words – Green jobs



A very important part of the renewable energy sector is the creation of employment or what is sometimes called green jobs. The picture above shows employment in different countries, including the USA. It is interesting to see that bioenergy generates considerable employment opportunities in many countries. This has a lot to do with the fact that bioenergy systems involve *a diversity of activities from the biomass feedstocks, to processing and transportation, to the conversion technologies. This cuts across various sectors, like agriculture, forestry, transport and energy.*

Who knows?

The ***Intergovernmental Panel on Climate Change*** is a scientific body, which reviews and assesses the most recent scientific, technical and socio-economic information produced from around the world relevant to the understanding of climate change. It was established by the United Nations Environment Programme and the World Meteorological Organization in 1988 to provide a transparent scientific view on the state of knowledge in climate change and its potential environmental and socio-economic impacts. Thousands of scientists from all over the world contribute to the work of the Intergovernmental Panel on Climate Change on a voluntary basis. The work of the Intergovernmental Panel on Climate Change closely relates to renewable energy, especially bioenergy and biofuels because there are important considerations around greenhouse gas emissions and different technologies and systems.

Check out http://www.ipcc.ch/ for more information.

Discussion point: Regional development

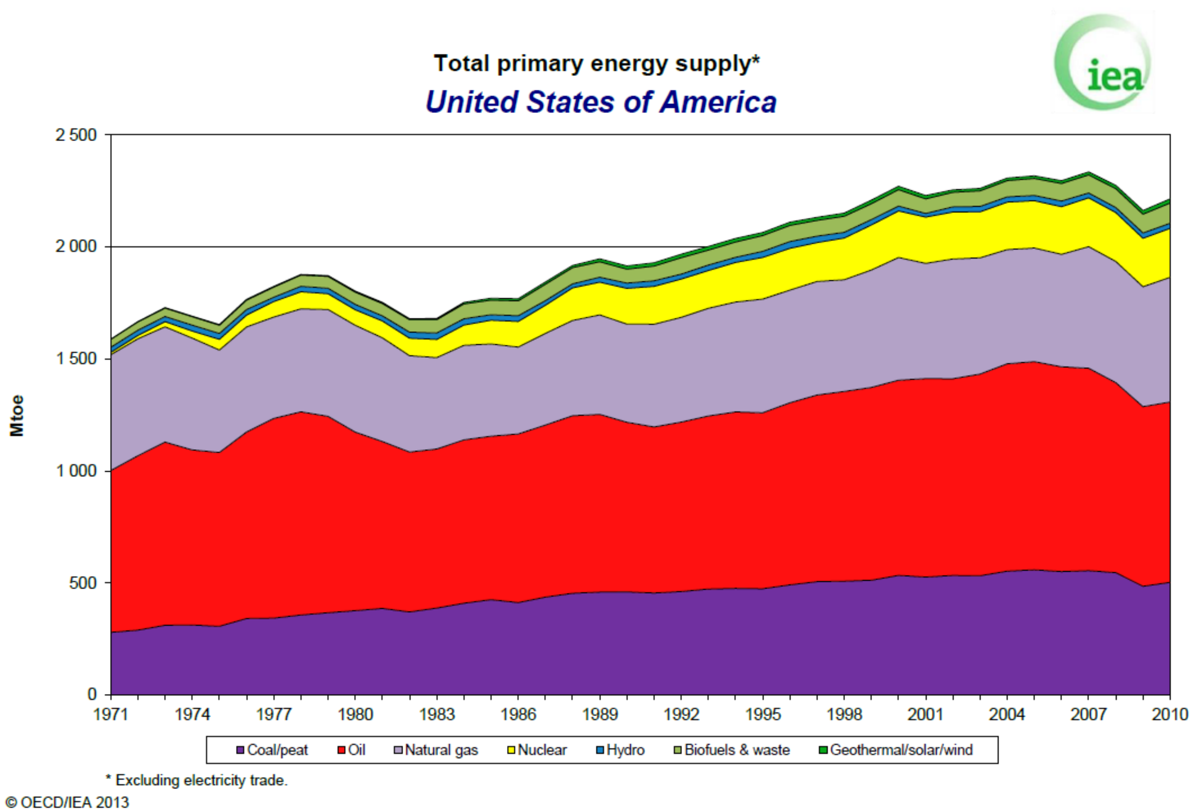
Modern large scale bioenergy technologies can be economically viable in large scale heat and electricity markets and they are particularly well-suited to certain niches, such as co-firing with fossil fuels, or in saw mills, wood working industries and other cases where biomass fuel supplies are readily available at low costs. Small scale heat and power projects also have applications within community settings where the wider environmental and social benefits can be realized and utilised. The many benefits and the generally acknowledged significant market potential for bioenergy has convinced many people and decision-makers that it is desirable for bioenergy to expand into a wider range of applications. In particular, communities can become direct stakeholders in their own energy supply either by producing fuels or through involvement in local projects.

Rural biogas

Bioenergy has provided millions of households around the world with incomes, livelihood activities and employment. The sustainability of bioenergy projects from a socio-economic perspective is connected to how they are perceived by society. Reducing greenhouse gas emissions as well as improving environmental protection and security of energy supply on a national level is an added bonus for local communities, but the driving forces for bioenergy development are much more likely employment or job creation, contribution to a regional economy and income improvements. Consequently, such benefits can result in increased social cohesion and stability that stem from the introduction of an employment and income-generating source. Other benefits include support of traditional industries, rural diversification, rural depopulation mitigation, and community empowerment.

Energy systems and sources

Based on IEA Energy Statistics, in 2010, over 83% of primary energy supply in the USA was based on fossil fuels, encompassing oil, coal and peat, and natural gas. The significant dependence on oil in the USA in the transport sector is a major issue as oil prices are expected to rise over the coming decades. Nuclear power is stable in the USA at 10% of energy supply, and it is difficult to see this expanding greatly (but that is up for debate). Biofuels and waste are just under 4% of energy supply, and investments are increasing, especially into biofuels for transport, as an alternative to petrol and diesel. Major challenges lay ahead for the USA to expand renewable energy sources.



The chart above for the USA tells us many important things about energy. First, the USA has been utilising large amounts of energy since the 1970s. Second, the primary energy supply is dominated by fossil fuels with coal and peat in dark purple, oil in red and natural gas in light *purple. Third, nuclear power in yellow plays a role in energy supply. Third, renewable energy looks rather small, but biofuels and waste in green are becoming an increasingly important source for the USA, particularly in terms of biofuels for transport. Always remember,* ***Total Primary Energy Supply (TPES)*** *means where we get our energy from in the first place, not like from the plug. In this chart, it shows different types of fossil fuels and renewable energy (including biofuels and waste). TPES is measured in this chart in* ***Millions of Tons of Oil Equivalent (MTOE)****. It is important to remember that final energy consumption is different to TPES as there are many energy losses before we can make use of energy services.*

In the news!

New biofuels offer hope to hungry world. In August 2012, the BBC reported that the poorest people in the world face additional problems as the price of staple foods increase. In this context, some reports claim that 40% of corn in the USA is being used to produce biofuels, and the renewable fuel standard mandate in the USA will require large amounts of domestic corn ethanol to be blended into the fuel supply. Ethanol based on corn is an example of first generation biofuels because it utilises food crops. The problems with producing large amounts of first generation biofuels based on food crops is particularly problematic when looking at impacts on the developing world and rising food prices. This is a key reason why developing and commercialising second generation biofuels is so important. Second generation biofuels use non-food materials, so they do not impact food prices. Additionally, these more advanced biofuels can reduce greenhouse gas emissions even more, and create new revenue streams for farmers and more jobs in rural areas. This is not to say that all first generation biofuels are bad. They just need to be monitored carefully and live up to sustainability and climate goals.

Funny and true?

To produce biomass for energy purposes, we need to use land. But we use land for many purposes, including for agriculture. The above cartoon jokes that it takes so long to get to the service station to fill up on biofuels because the plantation is so large. But it also raises the huge *issue about land use change associated with the production of biofuels. There is direct change to land use when biofuels displace some other activity, such as land for grazing cattle, or it can be indirect, when biofuels production moves into an area of land and pushes an activity into another area. In the worst case this could mean, forests are cut down for land to graze cattle because the land previously used is now covered with plantations for biofuels. This is a contentious and complex issue, which demands close attention to ensure that biofuels, as well as the agriculture and energy sectors are sustainable and smart.*

Sources

If you want to see where all the pictures, charts, photos, graphs, news and cartoons come from for this chapter on the USA, check out the sources.

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Chart – A picture tells 1000 words	Nieves Lopez Izquierdo, UNEP/GRID-Arendal	http://www.grida.no/graphicslib/detail/green-jobs_9a8b
Photo – Rural biogas	Lovisa Bjornsson	
Graph – Total primary energy supply	IEA Energy Statistics	http://www.iea.org/stats/pdf_graphs/USTPES.pdf
News	BBC News	http://www.bbc.co.uk/news/business-19179419
Cartoon	Cartoon Stock	http://www.cartoonstock.com/cartoonview.asp?catref=cman208

AUSTRALIA

With ample land, there is enormous potential to exploit biomass for energy purposes in Australia. Considerable research and development activities are also underway on biofuels from algae.

Australia is one of the largest countries in the world (at over 7.6 million square kilometres) and it also has one of the most urbanized populations with just 22 million people mostly concentrated in cities along on the coast. The capital city is Canberra, not Sydney or Melbourne as many expect. Much of the landscape is desert, but there is forests and rich agricultural land.

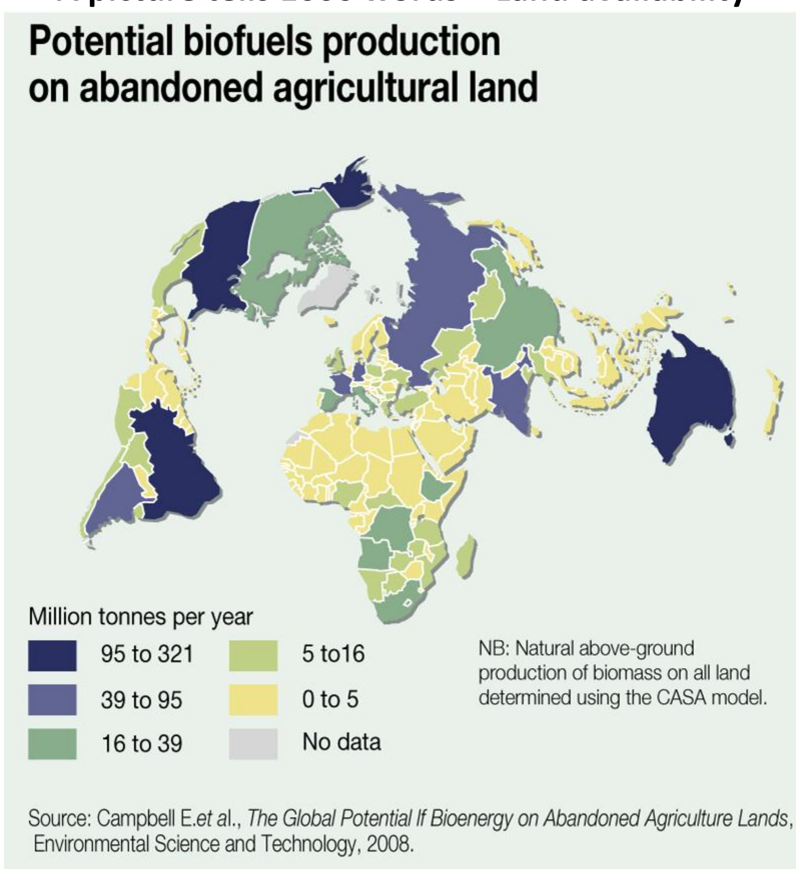
Australia in Oceania

National visions and actions

Australia has very large coal reserves, which can be used for domestic power production as well as exported to other parts of the world. One national strategy is to develop carbon capture and storage, so that coal can continued to be used but the associated greenhouse gas emissions can be captured and stored, rather than released into the atmosphere. However, at present carbon capture and storage technology is still very much under development, and it will be many decades before it is commercialised (if at all because the costs are so uncertain). Another vision that has been developed in Australia (and other parts of the world), and could grow quickly, is the idea of developing a *bioeconomy*. This is an emerging concept for the sustainable production and conversion of biomass for a range of food, health, fibre and industrial products and energy.

Tell me more about the bioeconomy? The concept of the bioeconomy is attracting increased attention and a number of countries and regions have developed strategies and visions about how to shift from a fossil-based economy to a bio-based economy. Put simply, biomass is the underpinning resource that drives the bioeconomy. In Australia, as in other places, an important challenge is to identify its role and particular strengths and opportunities within the emerging global bioeconomy. There is a strong connection between the bioeconomy and agriculture as well as the pressures to reduce greenhouse gas emissions, but at the same time ensure a stable food supply, maintain biodiversity and ecosystem services, and avoid energy security problems. The shift to a bioeconomy will demand strong policy, long-term collaborations, large investments in technologies and infrastructures, and ongoing public engagement. All in all, the challenges are large, but the opportunities are many.

A picture tells 1000 words – Land availability



There is abandoned agricultural land available for potential biofuels production. Hence biofuels production does not have to compete with food production. The picture above shows the distribution of abandoned agricultural land around the world. These lands are mostly situated in Brazil, USA and Australia. Take a close look at the picture above and see what it tells you about *available land. It is important to recognise that increased food and biofuels production means that the utilisation of crops and land should be optimized.*

Who knows?

Friends of the Earth are a global network representing more than 2 million activists in over 70 different countries. It is an organization or network that strives for a healthy and just world. While Friends of the Earth welcome biofuels that are environmentally and socially sustainable, they argue that many biofuels currently available are not meeting these criteria. They argue that biofuels produced from corn, sugar, soy and palm oil can increase soil erosion and air and water pollution, and in some cases these fuels even result in more greenhouse gas emissions than conventional gasoline. It is important to realize that Friends of the Earth are critical of biofuels in the context of large agro-industrial production. So it is mostly the current large-scale agricultural systems that Friends of the Earth have serious objections. This is in fact an on-going challenge for biofuels as they are part of larger unsustainable systems, like the agriculture, energy and transport sectors. It is very important to keep this point in mind when evaluating biofuels.

Check out http://www.foe.org/ for more information.

Discussion point: Carbon cycle

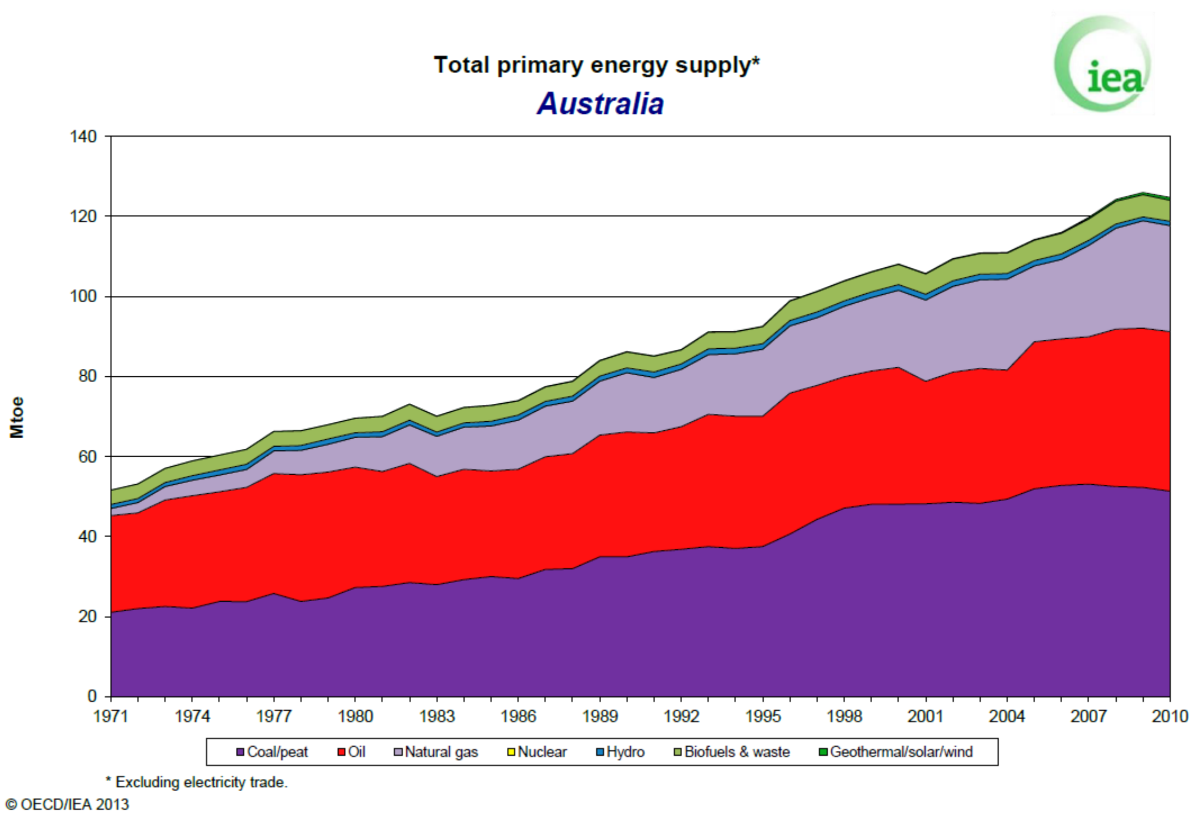
There has been considerable debate on bioenergy and climate change in recent years. Put simply, some bioenergy systems are better than others in terms of reducing greenhouse gas emissions. But it is important to always keep the carbon cycle in mind. The combustion of carbon based fuels (which encompasses fossil fuels like oil, coal and natural gas, but also biomass) releases carbon dioxide into the atmosphere, which is contributing to global warming. The crucial difference between fossil fuels and biomass lies in the timeframe over which carbon dioxide is released. Burning fossil fuels releases carbon that has been locked up for millions of years. However, burning biomass can be a part of the natural process called the carbon cycle – plants take up carbon dioxide when they grow, to construct the organic biological molecules that make up the bulk of their dry mass, and when the plants are eaten, burned or decomposed, the carbon is released again and it is returned to the pool of carbon dioxide in the atmosphere.

Plantation forests

Biomass for energy purposes can affect carbon emissions in several ways – it can serve as a substitute for fossil fuels, and it can also change the amount of carbon sequestered on land, effectively acting as a carbon sink. Increased afforestation or reforestation, as well as changes in cropland management practices can help in removing additional carbon dioxide from the atmosphere. Converting the harvested wood into wood products also acts as a carbon sink, as it increases the stock of carbon. However, forests and products derived from them have only a finite capacity to remove the carbon from the atmosphere, thus the main way to decrease the current carbon dioxide emissions is the substitution of fossil fuels with biomass and other renewables. Clearly, the carbon cycle is fundamental to the role of bioenergy systems in reducing greenhouse gas emissions and therefore as a way to mitigate against climate change.

Energy systems and sources

Based on IEA Energy Statistics, in 2010, a staggering 94% of primary energy supply in Australia was based on fossil fuels in the form of coal and peat, oil and natural gas. Renewable energy represented almost 6% of energy supply with biofuels and waste over 4% of that amount. So, the challenge is clear for Australia. To reduce greenhouse gas emissions means developing more renewable energy and cutting back on fossil fuels. But another important challenge for Australia to fight climate change means looking at exports of fossil fuels as well. This throws up many complex questions that will be debated in the coming decades. For increasing bioenergy and biofuels, it is a matter of greater investments coupled with political and public support.



The chart above helps us to understand energy in Australia. First, we can see that primary energy supply has increased since the 1970s until today. Second, fossil fuels dominate energy supply with coal in dark purple, oil in red, and natural gas in light purple. Third, biofuels and waste in green have been present in the energy supply for some time, but not really growing. In fact, the same can be said for renewable energy generally in Australia. Despite an abundance of opportunities to expand all forms of renewable energy, the potential remains untapped. Always remember, ***Total Primary Energy Supply (TPES)*** *means where we get our energy from in the first place, not like from the plug. In this chart, it shows different types of fossil fuels and renewable energy (including biofuels and waste). TPES is measured in this chart in* ***Millions of Tons of Oil Equivalent (MTOE)****. It is important to remember that final energy consumption is different to TPES as there are many energy losses before we can make use of energy services.*

In the news!

Cutting greenhouse gas emissions and fast? In April 2012, the BBC reported that the International Energy Agency has said that based on current trends, greenhouse gas emissions will double from 2009 to 2050. Nations can still keep the global temperature increase to below or near 2 degrees Celsius, which many experts and scientists believe is safe for humanity. But based on the projected increase in greenhouse gas emissions, the long-term temperature rise is likely to be at least 6 degrees Celsius. This is not good news. In order to reduce greenhouse gas emissions significantly and rapidly, it is clear that considerable investments are required in a mix of technologies – both in research and development, but more importantly in implementation. Bioenergy is one of many sources of renewable energy that must be tapped to a greater extent in order to shift away from fossil fuels. Energy efficiency is another area that can greatly reduce greenhouse gas emissions. Put simply, we will need all available technologies and systems to respond to the enormous challenge of global warming.

Funny and true?

The above cartoon suggests a direct link between fuels for cars and food. On the left, we can see a large red car, and on the right we can see the corn, and in between a woman filling up the car and looking at the corn, perhaps thinking if this is such a good idea to use food crops to produce fuels for vehicles? This is a major issue for biofuels. It is hotly debated what impacts some biofuels have had and will have on food prices. It is generally agreed that it is best to use a limited amount of food crops for fuels, as food is essential for life and should be made available *for consumption by people, and with a growing global population we will need all the food we can grow. So for biofuels it is very important to focus on non-food crops and wastes or residues.*

Sources

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Chart – A picture tells 1000 words	Nieves Lopez Izquierdo, UNEP/GRID-Arendal	http://www.grida.no/graphicslib/detail/potential-biofuels-production-on-abandoned-agricultural-land_f44f
Photo – Plantation forests	Kes McCormick	
Graph – Total primary energy supply	IEA Energy Statistics	http://www.iea.org/stats/pdf_graphs/AUTPES.pdf
News	BBC News	http://www.bbc.co.uk/news/science-environment-17847196
Cartoon	Cartoon Stock	http://www.cartoonstock.com/newscartoons/cartoonview.asp?catref=fgan8

ETHIOPIA

A distinction can be made between traditional and modern bioenergy. In the developing world, including Ethiopia, a transition is often required to develop more sustainable bioenergy systems.

Ethiopia is one of the most populous nations in Africa with over 84 million inhabitants and occupying 1.1 million square kilometres. With the capital at Addis Ababa, it is also a landlocked nation. Ethiopia is an ecologically diverse country, ranging from deserts in the East to tropical forests in the South. The population is dispersed in urban and rural areas, but urbanization has increased in certain periods.

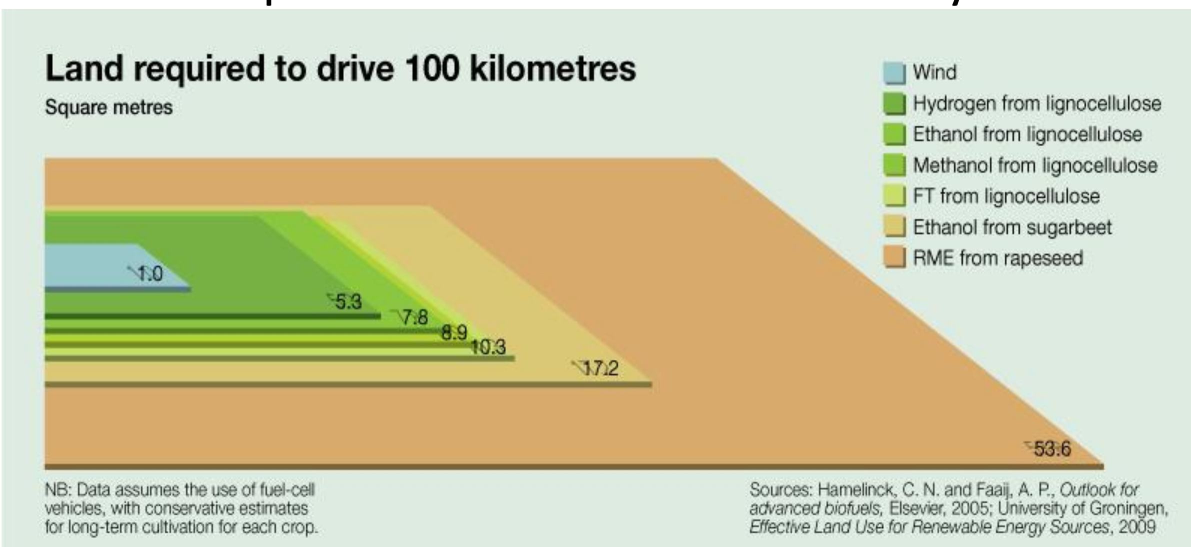
Ethiopia in Africa

National visions and actions

The potential to expand biomass for energy purposes in Africa is considerable, both for domestic use and exports. Ethiopia could be considered a typical country in Africa where a real challenge is to modernise bioenergy systems and ensure that the development of industries around bioenergy are sustainable and profitable. Ethiopia imports large amounts of petroleum for its fuel requirements, and the demand is rapidly increasing, which is associated with its growing economy and population, and its expanding infrastructure. Imported petroleum products account for a significant share of total import expenditure and therefore represent a major issue for the Ethiopian Government. However, the country has large amounts of arable land and a suitable climate for agricultural biofuels. The Ethiopian Government has expressed a vision to work towards the development of sustainable biofuels and has therefore entered into discussions with the *Roundtable on Sustainable Biofuels* on how to improve the current regulatory system and ensure that biofuels investments and developments are on a path towards sustainability.

What is the Roundtable on Sustainable Biofuels? It is an international initiative that brings together farmers, companies, non-governmental organizations, experts, governments, and inter-governmental agencies concerned with ensuring the sustainability of biofuels production and processing. Participation in the Roundtable on Sustainable Biofuels is open to any organization or group working in a field relevant to biofuels and sustainability. A certification system for biofuels sustainability standards, covering environmental, social and economic principles and criteria has been developed by the Roundtable on Sustainable Biofuels through a multi-stakeholder process. This is a very important initiative that has stimulated collaboration and action on working towards more sustainable biofuels.

A picture tells 1000 words – Land use efficiency



Land should be used more efficiently than it is today**.** The more fuel and food that can be retrieved from an area of land, the less competition there will be between bioenergy and food production, which is very important globally, but particularly in countries like Ethiopia. In this aspect, the effect of replacing the currently used biofuels with more advanced biofuels is significant. Check out the picture above. To take an example, the land required to produce enough fuel to drive 100 kilometres with a fuel cell car is less if lignocellulose, instead of sugar beet, is used for ethanol production. In fact, vehicles running on hydrogen (H_2) or lignocellulosic ethanol are better biofuels than the grain based bioethanol and biodiesel (rape methyl ester or RME), in terms of efficient land use.

Discussion point: Food security

The impact of biofuels on food security is a central argument often used against the expansion of biofuels. Indeed, biofuels produced from food crops (such as ethanol from corn) can increase food prices and complicate the ability to buy food in some parts of the world. If food crops are used for biofuels production and the targets set for biofuels usage are accomplished, the price on some food products could increase and this would have great impacts on people, especially in the developing world. However, the reasons for starvation are many and not only related to biofuels production. More importantly, there are ways to avoid the scenario where biofuels leads to negative impacts on food production. There are for example large differences between biofuels and the land required to produce them. Clearly, land should be used more efficiently than it is today**.** The more fuel and food that can be retrieved from an area of land, the less competition there will be between bioenergy and food production. In this aspect, the effect of replacing the currently used biofuels with more advanced biofuels is significant.

Agricultural land

The development and commercialization of advanced biofuels is very important. Research in the bioenergy field is focusing on using alternatives to food crops as feedstock for biofuels production. These biofuels are often referred to as second generation biofuels. Today, most of the ethanol used is produced from corn in the USA or sugarcane in Brazil, this ethanol is referred to as first generation biofuels. The use of these resources for energy production can lead to increased food prices and greenhouse gas emissions. However, research all over the world is looking into the possibilities of using biomass that cannot be used for human consumption. In particular, residues from forestry and agriculture are being investigated as resources for ethanol production. This reduces the impact on food prices, greenhouse gas emissions, land use change, biodiversity, and energy security. There are considerable expectations on second generation biofuels.

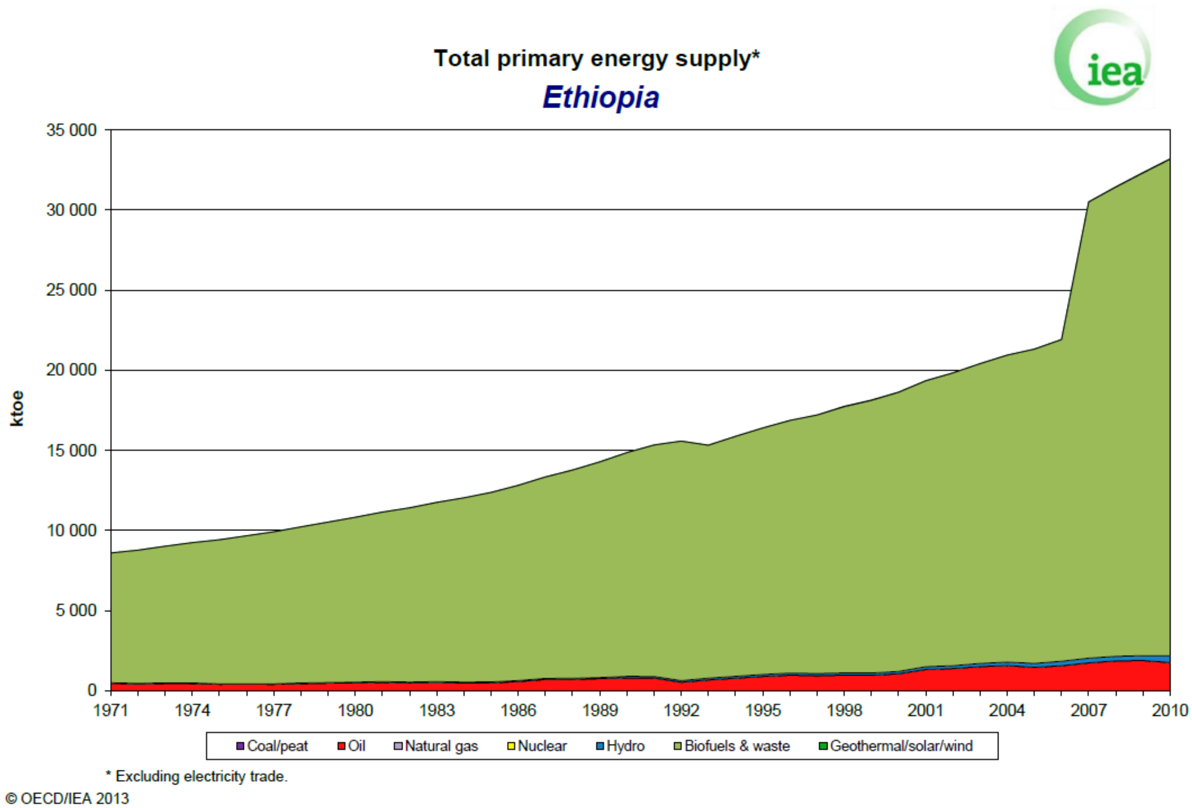
Who knows?

Founded in 2009, the ***International Renewable Energy Agency*** is an inter-governmental organisation dedicated to promoting renewable energy. Its key objective is to promote the widespread and increased adoption and the sustainable use of all forms of renewable energy. This encompasses energy produced from renewable sources in a sustainable manner, which include bioenergy, geothermal energy, hydropower, ocean, solar, and wind energy. The International Renewable Energy Agency is an important new international network and organisation that is working to expand renewable energy globally, and ensure that all companies and organisations working with different forms of renewable energy are part of a team that collaborates. A challenge for representing interests in bioenergy and biofuels is that they are so diverse because there are a variety of technologies, resources and systems.

Check out http://www.irena.org/ for more information.

Energy systems and sources

Based on IEA Energy Statistics, in 2010, some 92% of primary energy supply in Ethiopia was from biofuels and waste, while 7% was from oil, and about 1% based on hydropower. Ethiopia is faced with multiple challenges on energy, which are directly connected to development issues, particularly expanding electricity supply and distribution. Developing modern, sustainable and renewable energy systems is paramount. Bioenergy can be a key part of this transition, particularly because traditional biomass for energy underpins the current energy system.

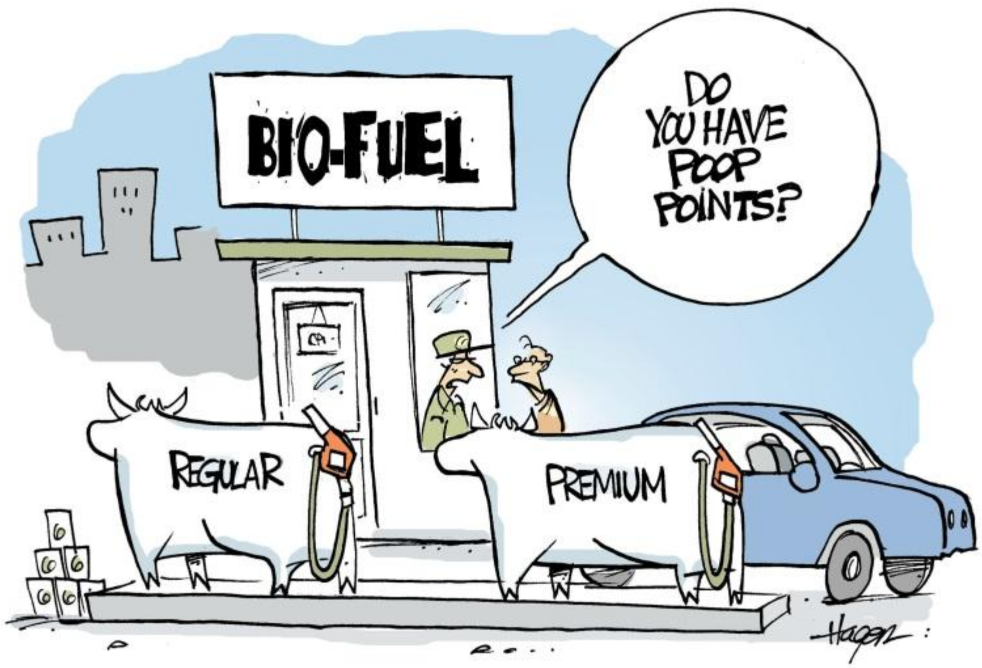


The chart above really tells a story about energy systems in Ethiopia. First, it is clear that biofuels and waste dominate in green. Oil is also present in red, but still dwarfed by biofuels and waste. This suggests that considerable development is needed in the energy and electricity sectors. Second, we can see a quick jump in the use of biofuels and waste in 2006 suggesting increasing energy demands. Always remember, ***Total Primary Energy Supply (TPES)*** *means where we get our energy from in the first place, not like from the plug. In this chart, it shows different types of fossil fuels and renewable energy (including biofuels and waste). TPES is measured in this chart in* ***Millions of Tons of Oil Equivalent (MTOE)****. It is important to remember that final energy consumption is different to TPES as there are many energy losses before we can make use of energy services.*

In the news!

Renewables can fuel society. In May 2011, the BBC reported that renewable energy technologies could supply 80% of the world's energy needs by 2050 according to the Intergovernmental Panel on Climate Change. In fact, in a special report on renewable energy sources and climate change mitigation by the Intergovernmental Panel on Climate Change, it shows that almost half of current investment in electricity generation is going into renewables. However, future development will depend on the "right" policies being in place. Importantly, there is more than enough renewable energy potential to meet current and future energy demands. Today, bioenergy is the largest renewable energy source. However, some bioenergy production is not sustainable. Of the various renewable energy technologies available, bioenergy is assessed by the Intergovernmental Panel on Climate Change as large, long-term potential for growth, along with solar and wind. Of course, we will need all renewables to be developed – from bioenergy to solar and wind to geothermal and hydro. The challenge is to ensure policies stimulate investments.

Funny and true?



The cartoon above makes some fun about biofuels for transport. But it also highlights a few key points. To begin with it shows regular and premium, which is just a couple of options, but when it comes to biofuels for transport there are a diversity of fuels and ways to produce them. The most common fuels available at present are ethanol, biodiesel and biogas. But there is a very wide variety of raw materials, processes and technologies that are available today and being developed. One of the most common systems is ethanol based on sugarcane, which often also involves the production of sugar as well as using the waste materials for heat and electricity. More advanced biofuels are being developed.

Sources

If you want to see where all the pictures, charts, photos, graphs, news and cartoons come from for this chapter on Ethiopia, check out the sources.

Item	Source	Link
Flag	CIA World Factbook	https://www.cia.gov/library/publications/the-world-factbook/geos/et.html
Map	CIA World Factbook	https://www.cia.gov/library/publications/the-world-factbook/geos/et.html
Chart – A picture tells 1000 words	Riccardo Pravettoni, UNEP/GRID-Arendal	http://www.grida.no/graphicslib/detail/land-required-to-drive-100-kilometres_2e42
Photo – Agricultural land	Kes McCormick	
Graph – Total primary energy supply	IEA Energy Statistics	http://www.iea.org/stats/pdf_graphs/ETTPES.pdf
News	BBC News	http://www.bbc.co.uk/news/science-environment-13337864
Cartoon	Cartoon Stock	http://www.cartoonstock.com/cartoonview.asp?catref=rhan834

REFLECTIONS

This guide provides a glimpse into the world of bioenergy and the emerging advanced bioeconomy. The six chapters in this guide describe the development of bioenergy in different countries spread across the continents of the world, including Sweden, Canada, Brazil, Australia, China, USA and Ethiopia. The information in the chapters is both specific to these countries, but also provides broader perspectives on bioenergy. Bioenergy has massive potential. But a key theme throughout this guide is the importance of strong sustainability standards.

The ***national visions and actions*** of these countries encompass breaking dependence on oil in Sweden, 5 year plans and renewable energy in China, the National Alcohol Programme in Brazil, the Blueprint for a Secure Energy Future in the USA, the development of the bioeconomy in Australia (and globally), and the participation of Ethiopia in the Roundtable on Sustainable Biofuels. All of these activities are directly connected to bioenergy systems and demonstrate how bioenergy fits into many different visions and actions.

A picture can tell 1000 words. This guide utilises some fantastic ***pictures and charts*** developed by GRID-Arendal & UNEP (2011). These cover forest carbon sequestration, crop production and water scarcity, feedstock efficiency and environmental impacts, green jobs, land availability, and land use efficiency. While these pictures contain complex information and concepts (as well as many assumptions that deserve discussion), the purpose of including them in this guide is provide important insights into bioenergy and topics for debate.

There are many ***organisations*** working with renewable energy and bioenergy around the world. This guide highlights just a few, including the International Energy Agency, the World Bioenergy Association, Greenpeace, the Intergovernmental Panel on Climate Change, Friends of the Earth, and the International Renewable Energy Agency. Be sure to check out their websites for a wealth of further information. These organisations provide different perspectives on bioenergy and how it should be developed and evaluated, particularly from a global viewpoint.

There is a lot to discuss when it comes to bioenergy. This guide briefly presents biomass resources (focusing on agriculture and forestry), international trade, ecological systems (particularly biodiversity and soil fertility), regional development, the carbon cycle, and food security (related to land use and new technologies). These ***issues*** are all connected and overlap. There are different viewpoints on these issues, particularly related to the impacts (both positive and negative) of bioenergy systems. To help you navigate and form your own opinion we have suggested a congress role play in the end of the book. Moreover, whenever you want more information, or are uncertain of a term just click on the hyperlink and you will get more information.

This guide provides some charts based on ***statistics*** from the IEA (2010) as a way to highlight the differences and similarities in energy systems (particularly with respect to the role of renewable energy and bioenergy) between the countries. The charts show the development of different energy sources over time. Look carefully at these charts to really understand a little more about energy systems. But be aware that there are different ways to present statistics and compare countries. Have a look on the internet for other sources of information on energy systems.

Bioenergy has attracted considerable media attention in recent years. In this guide there are some ***news stories*** on bioenergy from the BBC covering certification schemes for biofuels in Europe, wood as a resource for energy purposes, expanding bioenergy and implications for food crises, the development of more advanced biofuels, cutting greenhouse gas emissions, and the potentials for expanding renewables and bioenergy. The BBC is a respected news organisation and provides some insightful news stories on bioenergy.

And finally, there are some ***cartoons*** in this guide that poke fun at bioenergy. At the same time these cartoons raise highlights key aspects of bioenergy, including the diversity of ways biomass can be utilised for energy purposes, the different biofuels for transport available today, the use of biofuels for aeroplanes, land use and biomass production, utilising food crops for biofuels, and the development of advanced biofuels. These cartoons depict some of the “big” challenges and opportunities for bioenergy.

And now that you have read a lot about bioenergy, why not get a bit more practical with some ***experiments and exercises***. In the following pages is an experiment on how to build a biogas reactor, produce biodiesel, undertake a Life Cycle Assessment (LCA) as well as debate biofuels in a congress setting. There are also links to other exercises, which could increase your understanding of bioenergy. All these tasks are challenging, fun and you can learn a lot more about bioenergy. For the practical experiments be sure to do this with a teacher and be careful as the process can be dangerous if not done safely. For the LCA and the congress exercises, this really requires some teamwork and discussion to explore all the key issues. Good luck!

LAB EXPERIMENTS

Here are some simple experiments. However, experimental work always requires a proper safety assessment, adequate equipment and sufficient training. These experiments should only be performed under the guidance of your teacher.

Building a biogas reactor

Biogas production or anaerobic digestion is a process that takes place spontaneously in nature provided that there is an air-free environment. Therefore, it is relatively simple to build your own biogas reactor. Biomass conversion to biogas is driven by a variety of micro-organisms depending on each other for an efficient conversion. These groups of micro-organisms have to be balanced for a successful process. To keep this balance, factors such as nutrient mixture, pH and temperature must be kept at an optimal level.

Main concepts

Here are some key concepts or terms that you need to understand to build a biogas reactor.

- Buffer: A solution consisting of a mixture of an acid and a base. It makes sure that the pH of a solution is kept in a set range.
- Methanogens: Micro-organisms (from the group called achaea*)* that converts either acetic acid or H_2 and CO_2 to CH_4 in a biogas process.
- Volatile fatty acids (VFAs): These are short chain fatty acids that are volatile at room temperature. Acetate, propionate and butyrate are VFAs produced and consumed in the biogas process.
- Enzymes: Catalysts that drive or accelerate biological reactions. For example, they can be seen as scissors cutting the cellulose. Enzymes also accelerate nutrient consumption both in humans and in micro-organisms.
- Fermentation: A metabolic process where energy is released by nutrient oxidation, resulting in the reduction of a molecule produced in the same process. Typical examples of fermentation processes are ethanol production in yeast or H_2 production in fermentative bacteria in a biogas process.

Equipment	**Consumables**
Flask Balloon Tape Oven	Cattle manure Plant material Buffer

Procedure

There are 4 key steps in building a biogas reactor:

1. Add cattle manure, plant material (50:50) and a buffer (pH 7) to a flask approximately 1/3 of the total volume with 2/3 empty.
2. Use a balloon to separate the atmosphere in the flask from air. Make sure it is properly closed by securing the balloon on the flask with tape.
3. The flask can be placed in an oven at 55˚C to speed up the rate of the reaction. However, this is not necessary. The flask can also be placed at room temperature without any problem.
4. You can follow the experiment by measuring the volume of the balloon weekly during several weeks.

Key points

In order for you to develop a successful biogas process you should keep these factors in mind.

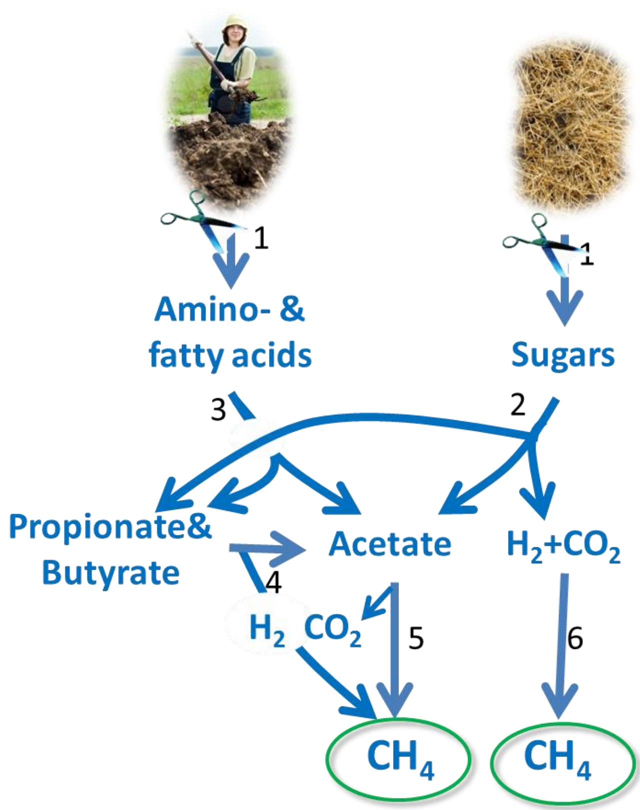
- The culture should be anaerobic meaning that there should be no air present. Therefore you should use a flask with a little balloon on top. The flask should be separated from air.
- The carbon (C) and nitrogen (N) contents should be balanced. That is why you should mix cattle faeces with plant material (50:50). The faeces are both an excellent source of proteins – rich in N – and it is a natural source of micro-organisms that are the drivers of the process. Plant material – rich in carbohydrates (C) – is degraded and converted to biogas. Also the protein and lipids present in the faeces are converted to biogas.
- For biogas production the pH should be kept close to 7. In a well-balanced biogas process, the pH is maintained in this range, and a buffer is not required. However, if the environment in the flask becomes too acid, the biogas producers (the methanogens) become inhibited, resulting in H_2 formation instead of CH_4. Increased H_2 formation inhibits oxidation of VFA) and acid decreases the pH even further. Altogether decreased pH leads to reduced CH_4 production.
- The flask should be securely closed and kept in a safe place, to avoid the risk of explosion. CH_4 and H_2 are explosive gases.

- Like most other chemical reactions, the biogas process can be faster by increasing the temperature. However, it should not exceed 55˚C, because then an essential part of the consortia will die.
- You should wear gloves and a lab coat at all time when working with your experiment and wash your hands carefully.

Summary

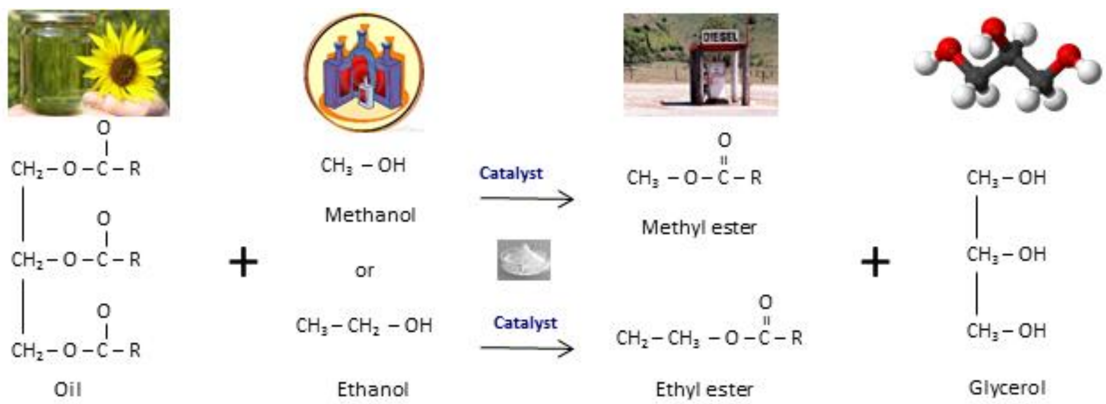
To summarize the biology of the biogas process there are 6 essential reactions (see picture below).

1. The complex plant material is cut down to sugar residues and the proteins and lipids in the cattle faeces are degraded to amino acids and fatty acids by enzymes produced by bacteria.
2. The sugars are fermented to VFAs (propionate, butyrate and acetate), H_2 and CO_2 by fermentative bacteria.
3. The amino and fatty acids are converted to VFAs and H_2 by fermentative bacteria.
4. Propionate and butyrate are oxidised to acetate by oxidising bacteria.
5. Acetate is converted to CH_4 and CO_2 by methanogens.
6. CO_2 and H_2 are converted to methane by methanogens (achaea).



Producing biodiesel from vegetable oil

Biodiesel is essentially oil that has been transformed to an ester to make it easier to burn at room temperature. Biodiesel is commonly produced from vegetable oils, such as rape seeds, sunflower, soy beans, jatropha and palm oil. However, it can also be produced from algae and frying oil, which is a waste product from the food industry. Biodiesel production is a chemical reaction, in contrast to bioethanol and biogas production, which are biological reactions. This means that you will use a chemical (methoxide or ethoxide) instead of a micro-organism to speed up the reaction. The catalyst methoxide or ethoxide is formed by reacting sodium hydroxide (also known as lye) with an alcohol. It is also possible to use an acid as a catalyst, but the reaction is slower. In this exercise you will use ethanol and produce an ethyl ester (see picture below).



Equipment	Consumables
Water bath (60°C), Dense small ball (1-10 g/L) Glass beaker (1 L) Measuring cylinder for the viscosity measurement Aluminum foil for capping flasks	Vegetable oil without water and little amount of fatty acids Ethoxide or sodium hydroxide (lye) Ethanol (95-99% pure)

Main concepts

Here are some key concepts or terms that you need to understand the experiment.

- Transesterfication: The reaction in which the ester is formed is called transesterfication.
- Ethoxide: This is the catalyst in the reaction. This means that it reacts with the oil and ethanol and speeds up the transesterfication reaction without being consumed in the process.
- Glycerol: This is a waste product in the reaction. However, it can be used for production of renewable polymers or for production of biofuels, such as biobutanol, bioethanol or biogas.

Key points
Here are some important points to keep in mind, especially related to safety.

- You should use protected cloth, gloves and goggles during the exercise. The experiment should be performed under a fume hood or other well ventilated space. There is a risk of emission of toxic gases and fire.
- Be careful, ethoxide is highly basic and can cause burning of skin. Use gloves at all time.
- If the ethoxide gets in contact with skin rinse with cold water for at least half an hour.
- A safety check should be performed by the teacher and the student should be informed before conducting any of the laboratory exercise described in this guide.
- If the oil used in the experiment has already been used for cooking, make sure to filter out any food residues first, as they may interfere with the biodiesel production. Water and oil containing free fatty acids should be avoided during the reaction since it reacts and forms soap instead of esters. Water can be used after the reaction to wash the ethyl ester from glycerol.
- It is recommended to order the ethoxide from any chemical company. The reason for this is that traces of water in the ethoxide mixture can result in soap, instead of ester formation. By using commercial dry ethoxide the risk of soup formation is much less.
- To make ethoxide, mix 180 mL ethanol (95-99 %) with 2 g sodium hydroxide. Mix until the sodium hydroxide has completely dissolved (approximately 2 minutes). The reaction is highly exothermic so be careful with ignition. Prepare and use the ethoxide the same day.

Procedure
There are 8 key steps in producing biodiesel in this experiment.

1. Poor 0.5 L vegetable oil (with little water and free fatty acid content) in a glass beaker
2. Add either a) the ethoxide mixture (prepared by the teacher) or b) 2 g solid ethoxide and 180 mL ethanol.
3. Cover the flask with aluminium.
4. Mix the suspension carefully. Avoid shaking to prevent trapping air or foaming.
5. Put the mixture in a water bath at 60°C.
6. Keep track of the reaction by following the change in viscosity. Use a dense small ball (density should be approximately 1-10 g/L) with symmetric shape and put it in the beaker. Follow how deep it will fall with time. The more ethyl ester is formed, the faster it will fall. This is because the large molecules in the oil (triglycerides) are broken down to smaller units (the ester and glycerol). This reduction in molecule size leads to decreased viscosity and a decreased viscosity results in that the ball with fall more rapidly.
7. After two hours, put the biodiesel/glycerol mixture at room temperature for 30 minutes without mixing. This allows the glycerol and the esters to be separated in

two phases. You will see a dark layer in the bottom (glycerol) and a lighter layer at the top (ethyl ester).

8. Transfer the top layer to a new beaker marked Biodiesel.
9. The biodiesel –the ethyl ester – can now be used to run a small diesel engine. It can be used directly or mixed with commercial diesel. The produced biodiesel should not be stored more than 10 days. Only use the biodiesel in a lab environment. Don't bring it home.

Summary

As suggested, biodiesel production is a chemical reaction, in contrast to bioethanol and biogas production, which are biological reactions. This means that a chemical instead of a micro-organism is used to speed up the reaction. In industrial biodiesel production the alcohol methanol is generally used for producing a diesel compost of methyl ester. However, here ethanol was used in this experiment to avoid toxic gases. The biodiesel produced from methanol with a non-renewable origin is still referred to as renewable, since the alcohol content is less compared to the renewable oil content. It is common that biodiesel production is dependent on a non-renewable component.

EXPERIMENTS ONLINE

Here are some simple experiments. However, experimental work always requires a proper safety assessment, adequate equipment and sufficient training. These experiments should only be performed under the guidance of your teacher.

The microbial fuel cell: Producing electricity from yeast

by Dean Madden
Submitted 2010
In Science in School issue 14

This experiment designed by **Dean Madden** from the **National Centre for Biotechnology Education, University of Reading, UK** will show you how micro-organisms can be used to generate electricity. The microbial fuel cell reminds you of a battery. However, the beauty of the system is that waste water can be used as charger. Hence the great concern on how to handle waste water to not contaminate the lakes and oceans can become an excellent opportunity to generate electricity. This technique is still in its youth, however, there has been progress making scientists foresee a future using this technique. Now you can judge for yourself by doing the experiment. Moreover, by following the experiment you will better understand the biology of yeast, the organism generally used for bioethanol production. The experiment can be found on the open access peer-reviewed journal **Science in School** devoted to make science accessible for teacher and students.

See: http://www.scienceinschool.org/2010/issue14/fuelcell

Climate change: Measuring fuel efficiency

by Dudley Shallcross, Tim Harrison, Steve Henshaw and Linda Sellou
Submitted 2009
In Science in School issue 11

After reading this guide you have explored that there are a range of different biofuels and each of them have their concerns and challenges. One central issue that we have not discussed yet is the efficiency of these fuels. This is something that car manufactures consider carefully when they decide on which fuel to use in their cars. This is also closely linked to concerns about climate change and limiting greenhouse gas emissions. To give you more understanding on fuel efficiency and climate change we recommend this experiment designed by **Dudley Shallcross**, **Tim Harrison**, **Steve Henshaw** and **Linda Sellou** from the **School of Chemistry, University of Bristol, UK**. By undertaking this experiment you will learn about physics and chemistry in relation to climate change. The experiment can be found on the open-access peer-reviewed journal **Science in School** devoted to make science accessible for teacher and students.

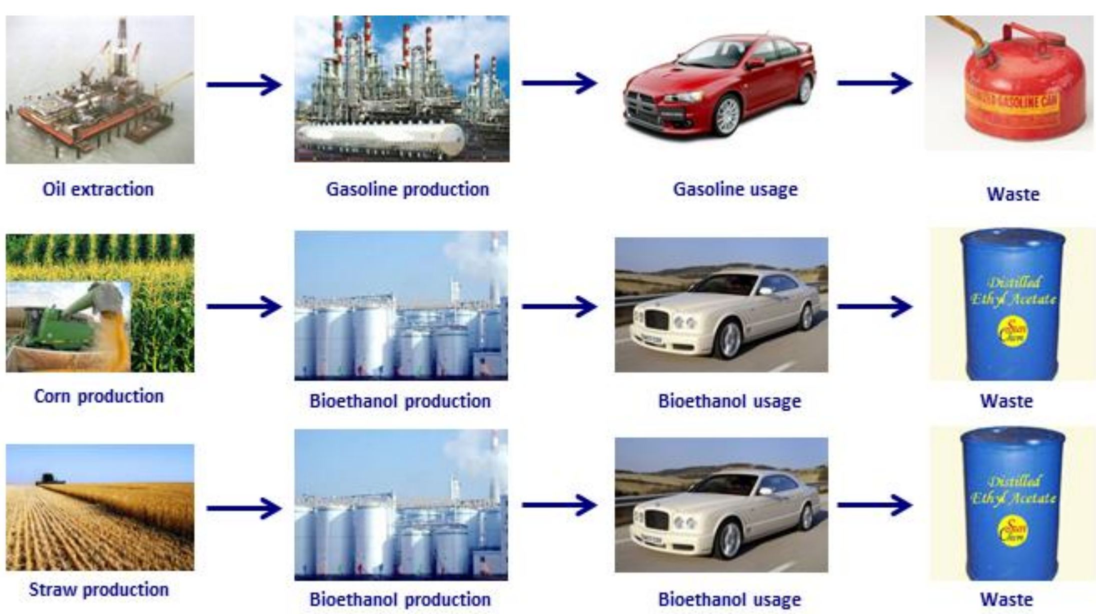
See: http://www.scienceinschool.org/2009/issue11/climate

CLASS EXERCISES

Undertaking a life cycle assessment

The impact of different fuels and energy sources on climate change is not obvious. All biofuels can appear to be beneficial in reducing greenhouse gas emissions compared to fossil fuels. However, after carefully considering all factors involved in the production and distribution of biofuels, another picture can emerge, where some biofuels can even produce more greenhouse gas emissions than fossil fuels. Another very important question about biofuels and fossil fuels relates to ethical and social issues (like the impacts on communities and labour conditions). A way of determine the actual impacts of different fuels is to do a so-called life cycle assessment (LCA). The following exercise aims to show you how to make such an analysis and at the same time foster your creativity and give you a context for discussions on biofuels and fossil fuels. Bear in mind that doing an LCA is not an easy task.

An LCA tries to sum up all the environmental (and social) impacts of each part of the process from production to usage and disposal of a product. The product in this case is biofuels (see picture below). It is defined as “an objective process to evaluate the environmental burdens associated with a product by identifying and quantifying energy and material usage and environmental releases, to assess the impact of the product”. In this exercise you will compare the environmental and social impacts of biofuels (focusing on ethanol based on corn or straw) with fossil fuels (focusing on oil). This will include both the positive and negative impacts, and discussion of the grey areas where it can be difficult to judge what kind of impacts can occur. You will do this in a qualitative way but normally an LCA would be quantitative.



To make an LCA you should make a list of all raw materials, energy inputs and waste production, then assess the impacts associated with each item, and think of options to improve the processes. Start with the raw materials. Each stage of the process requires inputs of raw materials. Identify some of the raw materials required for each stage. Is it possible to reuse any of these materials? When you have identified the raw materials you need to approximate the energy inputs. This is difficult. Also remember, that the LCA approach has the short coming in that the basis of calculations is the available data of each process. Innovations are being made all the time that makes the processes more energy efficient or more ethical. You should therefore be aware that what we know today might not be true tomorrow. Finally, you should identify what are the waste products in the process and what will happen to them.

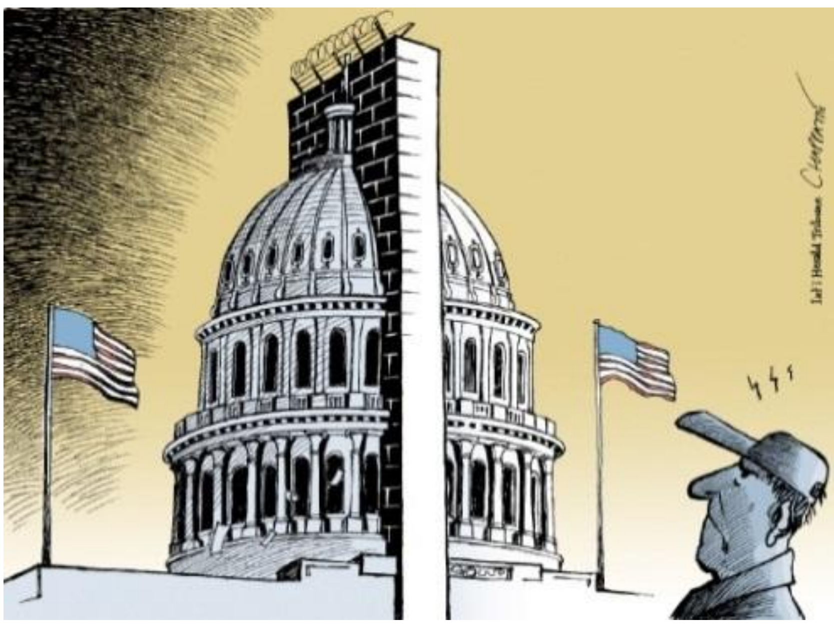
As suggested, you should assess the environmental and social impacts associated ethanol and oil. For understanding these impacts and doing this LCA exercise you can find lots of information on the internet. Be sure to look at "About Bioenergy" (visit http://aboutbioenergy.info/) and "Biofuels Vital Graphics" (visit http://www.grida.no/publications/vg/biofuels/). You will find various arguments in different discussion forums, websites and blogs. The challenge lies in selecting the most relevant and reliable information. The last part of the LCA is to think about and discuss options to improve the process. Here, again you will need to use the internet to help. In addition, you can look back over this guide for information. Finally, you should present your results to your fellow students and discuss the outcome.

Engaging in a congress role play

Throughout this guide you have learned about arguments for and against biofuels. You have also learned about different approaches by governments to reduce greenhouse gas emissions, secure jobs, and decrease the dependence of fossil fuels. Now it is time for you to discuss these issues and perhaps form your own opinion. One way of doing so is to do a congress role play. You will represent two parties where one wants to increase the subsidies and support for biofuels and the other party wants to use the funds for other purposes. You can even give your party a special name to represent your arguments. See below.

- ***Group A*** should find and develop arguments against investing in biofuels and decide on an alternative policy.

- ***Group B*** should find and develop arguments for investing in biofuels and decide on a policy on how to do it.



When searching for information you will find arguments for and against biofuels. Use this information to form your own opinion, but be careful of lobbying activity from different industries and groups. It is easy to find opinions on biofuels but sometimes difficult to find clear facts. Throughout this guide you can find both facts and opinions. Furthermore, complement the information in this guide with other useful resources by searching the internet and looking at "Biofuels Vital Graphics" (visit http://www.grida.no/publications/vg/biofuels/) and "About Bioenergy" (visit http://aboutbioenergy.info/).

When developing your arguments there are about many questions to ask. Are there any alternatives to biofuels? Why should we support biofuels production and use? Could government funds be invested by other means and still achieve the same goals on climate change and energy security? What have you learnt from this guide on biofuels and policy?

When you have all your arguments, select a few representatives that will bring forward the arguments in the discussion. Also select a chairperson that will guide the session and a note-taker to keep the key points from the debate. See below.

- Both parties will get the chance to bring up their three most important arguments. **Party A** starts by presenting their proposal and giving one argument.

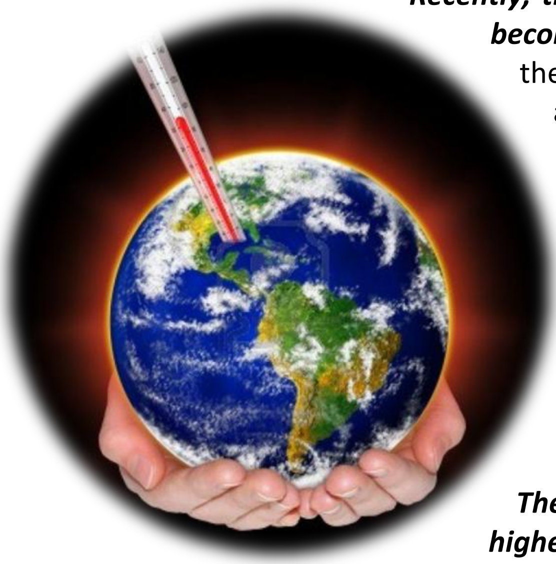
- **Party B** will then get the chance to debate the argument (make sure you are prepared for possible arguments). **Party A** will then get the chance to respond.

- Then it is **Party B** who can present their proposal and one argument, and continuing like that until the six arguments have been debated.

- Now it is time to vote. You may vote as your party but you have the freedom to vote for the other party if they have convinced you.

BACKGROUND MATERIAL

Sustainable Biofuels: Climate change



Recently, the need to ensure the sustainability of biofuels has become a very high priority. This has been exemplified by the development and use of sustainability standards and frameworks for biofuels. Among many important issues, including land use change, labour conditions, and environmental impacts, perhaps the most significant measure of sustainable biofuels relates to reducing greenhouse gas (GHG) emissions. The greenhouse effect is caused by GHG emissions such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that trap heat over the surface of the earth by absorbing and emitting radiation.

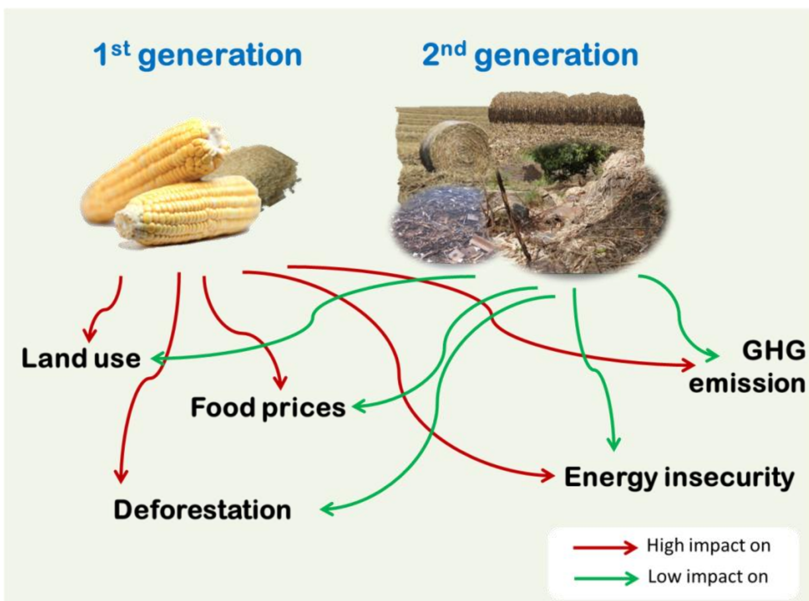
The combustion of fossil fuels - contributing to the highest emissions of GHG - is resulting in climate change, which in turn can lead to natural disasters such as flooding, hurricanes and heat waves. Emissions of CO_2 contribute to the strongest impact on the greenhouse effect since it is very abundant. While the potential of CH_4 and N_2O on global warming is 21 and 310 folds higher, their respective emissions is less hence the overall contribution is lower. The table below shows a list of greenhouse gases, their concentrations, anthropogenic sources and effect on global warming. This is a hugely important area for biofuels. It is imperative that biofuels can be part of making deep reductions in GHG emissions. When looking at different fuels and systems, it is important to keep in mind the amounts and types of GHG emissions associated with them.

Greenhouse gases	Chemical formula	Preindustrial concentration	Approximate concentration today	Anthropogenic sources (examples)	Global warming potential
Carbon dioxide	CO_2	280 ppmv	400 ppmv	Fossil fuel Land use change	1
Methane	CH_4	700 ppbv	1750 ppbv	Fossil fuel Rice paddles Waste dumps	21
Nitrous oxide	N_2O	275 ppbv	320 ppbv	Fertilizer Industrial combustions	310

Transport Biofuels: 1st and 2nd generation ethanol and 3rd generation biodiesel

Ethanol is the same alcohol as present in beer. The brewing process of beer is similar to that of bioethanol, which means that carbohydrates are fermented to alcohol by yeast. For the yeast this is simply a strategy to gain as much energy from the carbohydrates as possible when placed in a container without air. The origin of the carbohydrates could be many. Today, most of the ethanol used is produced from corn in the USA or sugar cane in Brazil, this ethanol is referred to as first generation ethanol. The use of these resources for energy production can sometimes lead to increased food prices and high greenhouse gas emissions.

The GHG emissions are mostly related to transporting and production of non-renewable fertilisers used in farming of corn in particular. Therefore the possibility of instead using biomass that cannot be used for human consumption, such as corn stover, sugar cane bagasse or wheat straw, is investigated world-wide. This so-called second-generation ethanol is developed with the intention to reduce the impact on food prices, GHG emissions, land use, deforestation and energy security. By integrating bioethanol with biogas production and production of other essential chemicals such as bioplastics in a so called biorefinery concept, these positive effects can be enhanced further.



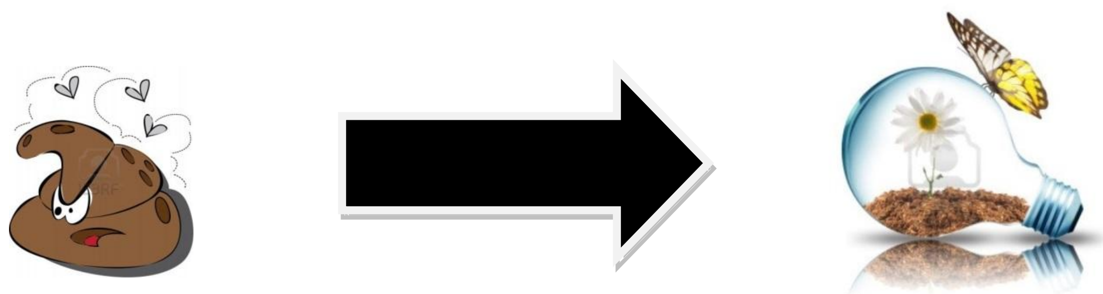
The figure above shows a simplified comparison between first and second generation bioethanol*.* This is a simplified illustration and it should be clarified that it is not always that black and white. In some cases first generation bioethanol could actually reduce the GHG emissions more than second generation, if sustainable practices have been followed in each step of the cropping and processing of the fuel and fossil fuels are avoided in the process. There are many issues to keep in mind when deciding if biofuels are sustainable or not, which makes the issue heavily debatable.

Turning to third generation biodiesel, algae are photosynthetic organisms like plants but they live in oceans and lakes; hence there is less competition for land for food production if algae instead of land crops are used for biodiesel production. The picture on the right shows algae in a pond. Moreover, biodiesel produced from algae – so called oilgae – can be very efficient. Algae produce 30 times more fuel per area of land than land crops such as soybeans. Many research groups also explore the possibility of producing hydrogen from algae as an alternative clean and efficient energy carrier. Another interesting source for biodiesel production is frying oil, which is a waste product from the food industry. Using waste products - instead of food crops - for fuel production, reduces both the impact the waste otherwise has on climate change and the impact biofuels have on food prices.

Biofuels Production: Fertilisers usage and biogas digestate

Fertilizers are minerals used to enhance plant growth. Both the production of food (crops and cattle) and biofuels (crops) are generally dependent on fertilizer addition. The amount of fertilizer required depends on the crop. However, production of fertilizers such as ammonium can lead to the emission of N_2O – a potent greenhouse gas – which causes climate change. Amongst other factors, the usage of fertilizers contributes to the fact that biofuels sometimes emit more GHG than gasoline. Bioethanol produced from corn (first generation ethanol) has been criticised as an example where the overall emissions of GHG in most cases is greater than if gasoline is used.

Another mineral used as fertilizer is phosphor. It is mined from rock reserves in a few places around the world. Similar to the oil crises, experts expect a fertilizer crisis, since phosphor rocks are not renewable and the phosphor storage is therefore depleting. When the availability is decreasing the price of fertilizers is increasing. This affects the cost for food production, which consequentially affects food prices. One way to decrease the dependence of fertilizers for biofuels production is to use biogas digestate.



Biogas digestate is the residue after biogas production. This product can be used as a fertiliser since it contains essential nutrients such as phosphor and nitrogen. In the biogas process, these nutrients are mineralised, meaning that they are transformed from an organic into an inorganic form that makes them easily assessable to the plants. Therefore, biogas digestate is generally effective in stimulating plant growth. Using the biogas digestate on the fields is an excellent way to recirculate nutrients. The biogas digestate can to some extent replace the use of mineral fertilizers that are non-renewable and have severe impacts on climate change. Biogas digestate can also replace manure and be used directly on the field reducing the smell, the concentration of pathogenic bacteria (causing sickness in humans) and, in some cases, increasing the efficiency. The figure above indicates that by converting manure with a bad smell to biogas one can potentially get both energy and a much nicer smelling fertiliser.

SOURCES

If you want to see where all the pictures, charts, photos, graphs, news and cartoons come from for the front and back covers, introduction, experiments and exercises, and background material, check out the sources.

Item	Source	Link
Front and back covers		
Bioenergy cloud	123rf	http://www.123rf.com/photo_16498754_abstract-word-cloud-for-biomass-with-related-tags-and-terms.html
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Introduction		
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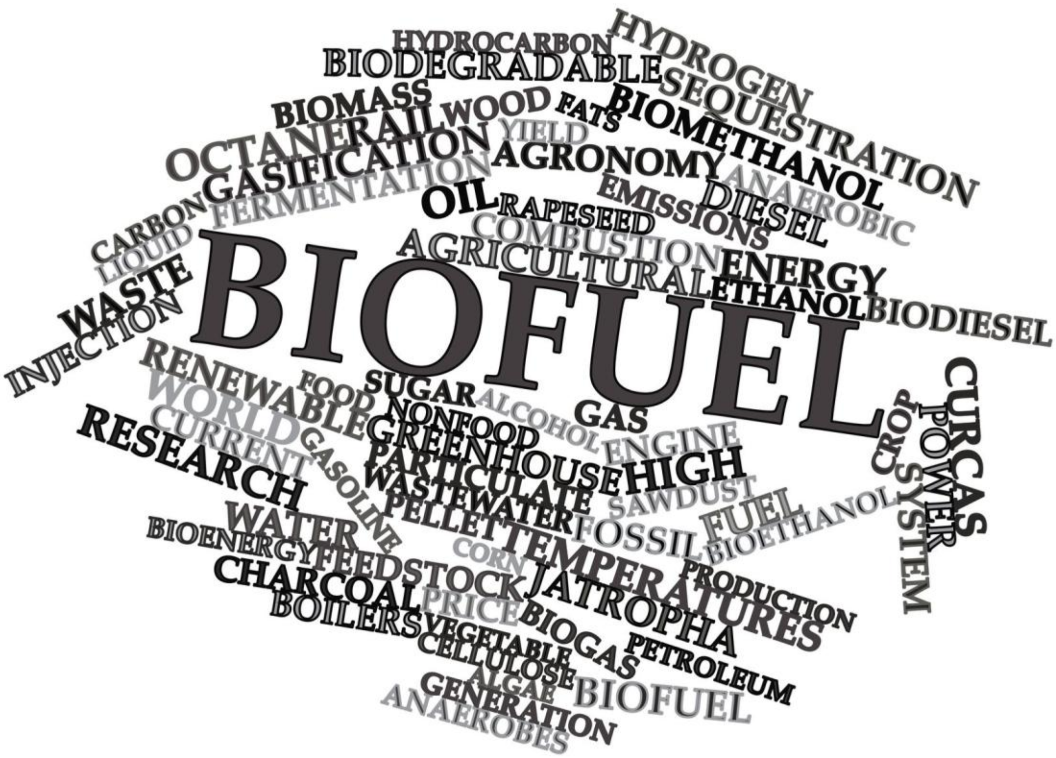
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