



Introduction and History of Bioenergy *how we got here and why it matters*

Lecture 1 - Early Bioenergy History

Welcome to BRR 350, An Introduction to Regional Bioenergy. We are going to start learning about bioenergy with a short review of the history of the field. Biomass was around before humans, so naturally human utilization of biomass for energy is almost as old as humans themselves. I like to start with this picture of a gas pump hostage situation because I think it captures our current addiction to carbon and the dual role bioenergy might play depending on what paths we choose. So lets get started!

Week 1 - Early & Recent Bioenergy History

-Learning Objectives-

- ▶ List some of the major historical steps in the development of bioenergy from the beginning of human civilization until today.
- ▶ Describe some of the people associated with these developments
- ▶ Identify something about carbon energy history that you would change if you could and discuss why you would change it.



Oil is not a bad thing
Coal is not a bad thing
Biomass is not a good thing

To appreciate where biomass utilization can improve things, we must learn to see our carbon resources objectively.



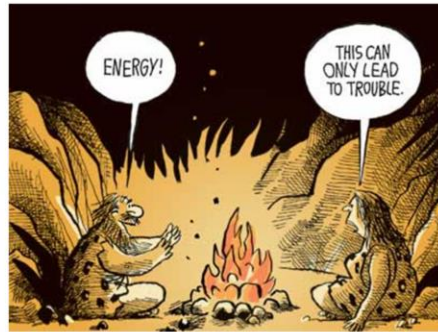
Oil is not a bad thing
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Stay objective - It's all just natural carbon!!

They all have strengths and weaknesses. So how did carbon become so important?

Carbon as an energy source started with fire

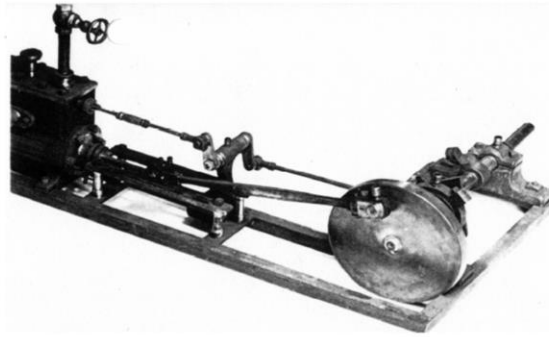
- ▶ Widespread use of fire by humans has been happening for over 100,000 years
- ▶ We still burn stuff because burning stuff is an efficient way to generate energy



Bioenergy has been around for as long as humans have had fire. Biomass was the simplest source of combustible carbon we could get our hands on and once we learned how to ignite it the rest was history. Humans love burning carbon because we live in a world made of carbon surrounded by an atmosphere full of oxygen. The combination of carbon and oxygen is just too good to pass up – plentiful reactants, easy reaction to start, great heat production. Combustion was and still is the king of bioenergy conversions in efficiency, ease, and global utilization.

After fire, the next big step for carbon was ethanol

- ▶ Ethanol candles and ethanol distillation approx 1100 – 1200's
- ▶ Ethanol cook stoves utilized in the 1500's
- ▶ Ethanol & turpentine powered the first engine in 1826



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Samuel Morey and one of the earliest internal combustion engines are shown here.

Ethanol has been around a loooong time. Humanity discovered fermentation before we figured out civilization and writing, but there isn't clear written evidence of alcohol distillation until 12th century Italy. Shortly after we learned how to distill and concentrate alcohol we learned how to use it for lighting and cooking. Ethanol seems to follow humanity and civilization, so it stands to reason that if a place with a form of writing had a large city (50,000+ population) it probably had some kind of alcohol distillation happening, regardless of when it existed (BC – AD).

Internet searching for aqua ardens (burning water), aqua flamens (flaming water), aqua vitae (water of life), and eau de vie (fruit brandies) can be used to dig deeper into the long and complex history of human's experiences with ethanol. Encyclopedia Britannica also provides more explanation; <http://www.britannica.com/EBchecked/topic/166115/distilled-spirit>

A good name to remember is Samuel Morey. He was quite a guy and played an important role as one of the premier engine inventors of his time. During his experiments, Morey discovered that the vapor of turpentine, when mixed with air, was explosive. He recognized its potential, developed an engine, published and patented the idea in 1826. Morey demonstrated his engine in New York and Philadelphia and there are eyewitness reports for both. In Philadelphia, he demonstrated it powering a boat and a wagon. Sadly, his contributions to the field went mostly unnoticed because others were working on competing and ultimately more successful designs at the same time. This is why it is important we remember him here.

Around the same time we also began using vegetable and fish oils for energy (light & heat)

- ▶ Olive oil has been a commercial industry since ancient Greece
- ▶ Herring, cod, and tuna oil since the middle ages (~1200 – 1300's)
- ▶ Whaling and whale oil became competitive in the 1700's



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Humanity has been enjoying animal and plant oils in foods and medicines for longer than we have had writing. However, as we began building larger structures and bigger “cities” a new industry around lighting emerged. Much like alcohol, there is compelling evidence to support the existence of candles and lamps in just about any place with a form of writing and a large city (50,000+ population) regardless of when it existed (BC – AD). So, if you’re looking to identify where in history humanity started using plant and animal oils for light/heat it is not unreasonable to assume ancient Egypt or Sumeria (Iraq).

Lamp fuels included all kinds of vegetable oils (castor, rapeseed, peanut); animal oils (especially whale oil and tallow from beef or pork); refined turpentine from pine trees; and alcohols, especially wood alcohol (methanol or methyl alcohol) and grain alcohol (ethanol or ethyl alcohol). The most popular lamp fuel in the U.S. before petroleum was a blend of alcohol and turpentine called “camphene” or simply “burning fluid” - <http://www.environmentalhistory.org/billkovarik/about-bk/research/henry-ford-charles-kettering-and-the-fuel-of-the-future/>

Some interesting sites with additional information are:

<http://www.historyoflighting.net/>

<http://www.ies.org/lighting/history/timeline-of-lighting.cfm>

Dr Brian Bowers "Lengthening the Day, A History of Lighting Technology" (Oxford University Press 1998)

Oils were great, but ethanol was better

- ▶ Ethanol was cheaper and more plentiful
- ▶ By the 1860's distilleries produced ~100 million gallons/year for heat/light
- ▶ In response to it's value, we taxed it so heavily petroleum became competitive



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Ethanol has always been “the people’s fuel”. It could be produced by anyone with a still and the feedstock for the process was everywhere. Ethanol stills were extremely commonplace in the 1800’s and it was being commercially produced around the time of the Civil War. Somewhat ironically, as petroleum was struggling to enter the market that ethanol had created/secured, ethanol was taxed incredibly heavily and petroleum (kerosene) became the preferred fuel almost overnight.

From <http://www.environmentalhistory.org/billkovarik/about-bk/research/henry-ford-charles-kettering-and-the-fuel-of-the-future/>;

“By the late 1830s, alcohol blends had replaced increasingly expensive whale oil in most parts of the country. It “easily took the lead as the illuminant” because it was “a decided improvement on other oils then in use,” (especially lard oils) according to a lamp manufacturer’s “History of Light.”²¹ By 1860, thousands of distilleries churned out at least 90 million gallons of alcohol per year for lighting.²² In the 1850s, camphene (at \$.50 per gallon) was cheaper than whale oil (\$1.30 to \$2.50 per gallon) and lard oil (90 cents per gallon). It was about the same price as coal oil, which was the product first marketed as “kerosene”²³ (literally “sun fuel”).

Kerosene from petroleum was a good fuel when it arrived in the 1860s. It was usually not too volatile and it burned brightly and it was fairly cheap. A gradual shift from camphene to kerosene might have occurred, but instead, a \$2.08 per gallon tax on alcohol was imposed in stages between 1862 and 1864 as part of the Internal Revenue Act to pay for the Civil War. The tax was meant to apply to beverage alcohol, but without any specific exemption, it was also applied to fuel and industrial uses for alcohol. “The imposition of the internal-revenue tax on distilled spirits ... increased the cost of this ‘burning fluid’ beyond the possibility of using it in competition with kerosene...,” said Rufus F. Herrick, an engineer with the Edison Electric Testing Laboratory who wrote one of the first books on the use of alcohol fuel.²⁴

While a gradual shift from burning fluid (or spirit lamps) to kerosene did occur in Europe during the last half of the 19th century, the American alcohol tax meant that kerosene became the primary fuel virtually overnight, and the distilleries making lamp fuel lost their markets. The tax “had the effect of upsetting [the distilleries] and in some cases destroying them,” said IRS commissioner David A. Wells in 1872. “The manufacture of burning fluid for lighting suddenly ceased; happily, it was replaced by petroleum, which was about to be discovered.”²⁵ Similarly, C.J. Zintheo, of the U.S. Department of Agriculture, said that 90 million gallons of alcohol per year were used for lighting, cooking, and industry before the tax was imposed.²⁶ Meanwhile, use of oil shot up from almost nothing in 1860 to over 200 million gallons in 1870.²⁷ “The effect was disastrous to great industries, which, if [they were to be] saved from ruin, had to be rapidly revolutionized,” according to Irish engineer Robert N. Tweedy.²⁸

Another key step was pine sap or “Naval Stores”

- ▶ From the middle ages (~1200 – 1300's) we have been tapping pines
- ▶ Major commercial US industry from 1700's until the 1960's



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Believe it or not, the south was primarily settled for the value it brought to the country in the form of pine sap. The North Carolina Tar heels are named after the laborers that used to harvest the sap or “pine tar”. Prior to oil, pine sap was a resource that nations went to war over – it was used to make massive wooden ships functional (thus supporting cross-ocean travel) and when it was distilled it produced a variety of chemicals that were hugely valued at the time, most notably turpentine. Turpentine was used for a lot of things back then, but maybe one of the most important markets was lamp oil.

The naval stores industry still exists today (<http://www.pinechemicals.org/>), but they are no longer produced by tapping trees. These days, naval stores are generally referred to as pine chemicals and tall oils which are byproducts of the pulping industry that generates paper. This is still a commercial industry, but it is a fraction of what it once was.

We have only been refining petroleum and using it commercially for about 150 years ...

- ▶ We all know people who grew up without plastic
- ▶ You may even know people who grew up without oil (petroleum)
- ▶ Kerosene drove the development of oil refining in the 1850's



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And then there was oil.

Just like ethanol and turpentine, the demand for lighting drove a significant amount of the development of oil production and refining. Kerosene was a huge deal and became an even bigger deal after that ethanol tax. The world's thirst for cheap, clean energy in the form of lighting caused oil production to skyrocket by the 1870's.

Petroleum was not useful until we learned how to refine it into its pieces. Samuel Martin Kier is often credited with founding the American petroleum refining industry. He was the first person in the U.S. to refine crude oil into lamp oil back in 1851. He started the first large scale oil refinery (5 barrel capacity) using oil from Edwin Drake's first production well. Edwin Drake is famous for pioneering an important method for producing oil from the ground and because the principle behind his idea is still employed today by many companies drilling for oil, he is often credited for being the first person to successfully drill for oil. A little after kerosene, but equally important for the industry was the development of something called "fractional distillation". Fractional distillation of oil to produce a variety of products was first done by Benjamin Silliman in 1854 and in many ways this advancement laid the foundation for the petroleum refineries of today.

We have this recurring tendency to use natural resources faster than they can re-grow



There is an argument that refining petroleum actually “saved the whales” and “protected the piney woods”.



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I do not agree with this argument. We do often use natural resources in an unsustainable manner, but alcohol fuels were quickly overtaking whale oil before kerosene became a thing. The most popular lamp fuel of the time contained turpentine, so perhaps kerosene helped save the piney woods by decreasing the market value of naval stores, but I think even that is a stretch because while the whale oil industry completely collapsed based on market factors, the naval stores industry continued growing until the 1940's. The lesson here is that markets are decided based on politics (taxes/regs), economics (supply/demand/cost), and timing.

In the 1890's ethanol was powering farm equipment and ironically, Rudolf Diesel built his 1st prototype engine

- ▶ Diesel engines became the most efficient engine available, far better than steam and ethanol engines
- ▶ By 1900 diesel engines were running on peanut oil
- ▶ By 1910 diesel engines were the preferred power source for heavy equipment (ships, factories, tractors, etc.)



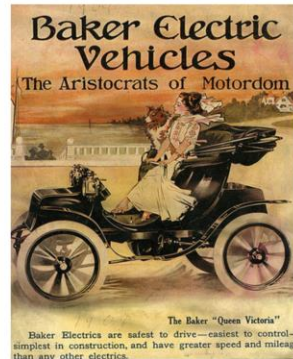
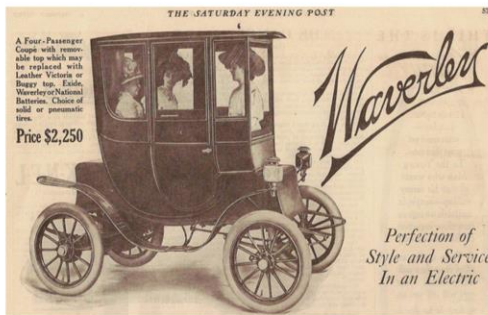
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Once we sorted out oil refining we all of a sudden had a variety of fuel sources to choose from. By the 1890's there were dozens of internal combustion and steam engine designs that ran on a dizzying spectrum of fuels – these were soundly defeated by the diesel engine. The design basis for this engine was fuel flexibility and rote efficiency. Rudolf succeeded in hitting his mark, thus giving the world an engine design that it continues to be used today, over 120 years later.

Important to note that electric engines & vehicles became competitive at nearly the same time

- ▶ The first electric vehicle was built in the 1830's
- ▶ Electric taxi cabs in NYC by the 1890's
- ▶ By early 1900's electric vehicles are produced commercially



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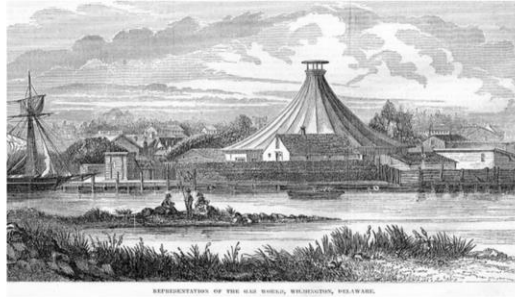
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When I first learned about this I had to let it sink in. Much like the whale oil, naval stores, ethanol, petroleum battles for market share, combustion vehicles were competing with electric vehicles. For a variety of reasons combustion vehicles advanced and electric vehicles were largely forgotten by the mainstream, until a relatively recent resurgence. It is ironic that the same reasons electric vehicles were compelling in the 1900's, are the same reasons they are compelling now.

It will be interesting to watch the electric car industry this time around. If aluminum welding becomes more standard, the price of carbon fiber drops, and the battery component recycling becomes normal it could end up being quite competitive. However, those first two conditions also help combustion vehicles, so its far from a simple projection.

Natural gas only became the standard in the 1950's ...

- ▶ From the 1790's to the 1950's most gas needs were met using municipal gasifiers known as "gasworks".

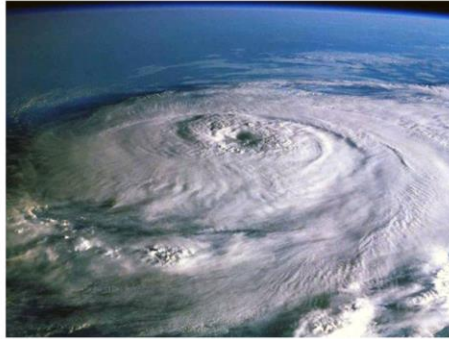


- ▶ Gasifiers lit towns, heated hospitals, and supported industries
- ▶ Home heating done with wood and coal, lighting done with candles and oil
- ▶ Electric lighting only became widespread in the 1920-1930's ...

As we become immersed in the recent natural gas bonanza, it is important to remember how new this resource really is. We have not always had it and we have not always used it. In many senses it is a very new fuel, much younger than ethanol, naval stores, coal, and petroleum. As more and more of our infrastructure is powered on natural gas, we need to consider what this will mean for our future.

Early 1900's were a turning point for carbon as an energy source

- ▶ Ethanol, diesel, gasoline, and electric engines are all available and competing
- ▶ Vehicles are creating incredible demand for portable energy
- ▶ Mass production and assembly lines have just been invented



A perfect storm
for carbon energy

The government policies and market conditions of the 19th century are largely responsible for the status quo of 21st century.

Timeline Recap

- ▶ Ancient history shows usefulness of fire and alcohol
- ▶ 1826 – Ethanol is used in 1st internal combustion engine
- ▶ 1851 – Oil is 1st refined into something useful, “kerosene”
- ▶ 1864 – Ethanol taxed so heavily, oil becomes major success
- ▶ 1890’s – Electric taxis in NYC
- ▶ 1900 – Diesel engines running on peanut oil, best engine design
- ▶ 1950’s – U.S. moves from municipal gasifiers to natural gas

If a market already exists, a “better” way of doing things can become the new standard very quickly

Next Lecture – Recent Bioenergy History

