Biorefining

Lecture 20 – Biorefining in North America

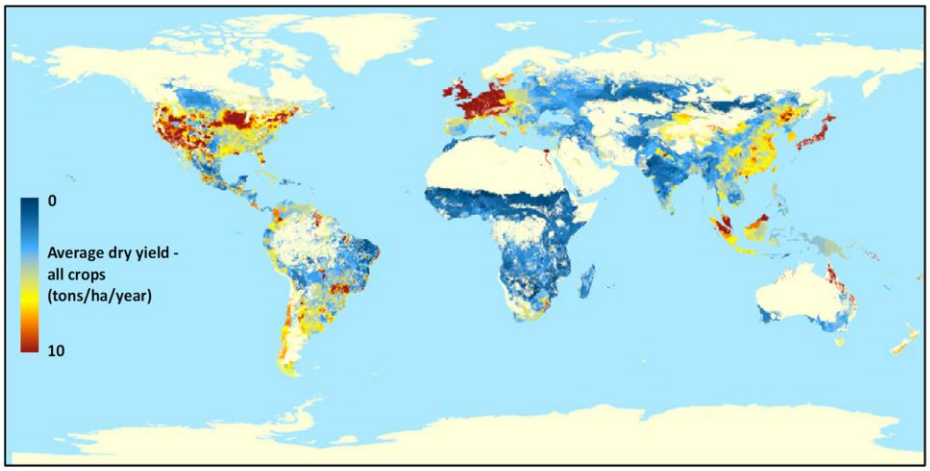
http://www.diamondgforestproducts.com/index.html

When you have a chance please visit the attached link on a company called Diamond G Forest Products in GA. This is a modern day pine tapping, naval stores business. They are using some more advanced methods and making a high quality tree resin product that is getting attention from local green chemicals producers. In some senses, this is an exciting development because it signifies an attempt to modernize naval stores technology along with DOE driven efforts like the PETRO program. Worth thinking about.

Week 8 – Biorefining
-Learning Objectives-

- Illustrate how the 4 common denominators of the bioenergy industry can be used to explain a commercialized bioenergy process and a non-commercialized bioenergy process.
- Identify and briefly explain an "integrated biorefinery" using the necessary conversion steps
- Recall some of the strengths and challenges involved in building biorefineries. Be prepared to explain how a biorefinery could be developed to be sustainable

Biorefining will not replace oil or coal BUT it can improve the whole system by using this strength;

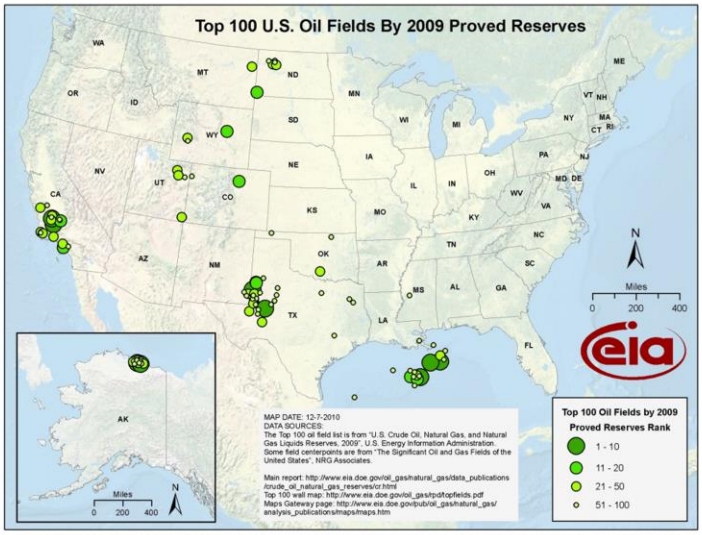


West et al. | www.pnas.org/cgi/doi/10.1073/pnas.1011078107

So back to this map. At this point I hope it is fairly clear that ….

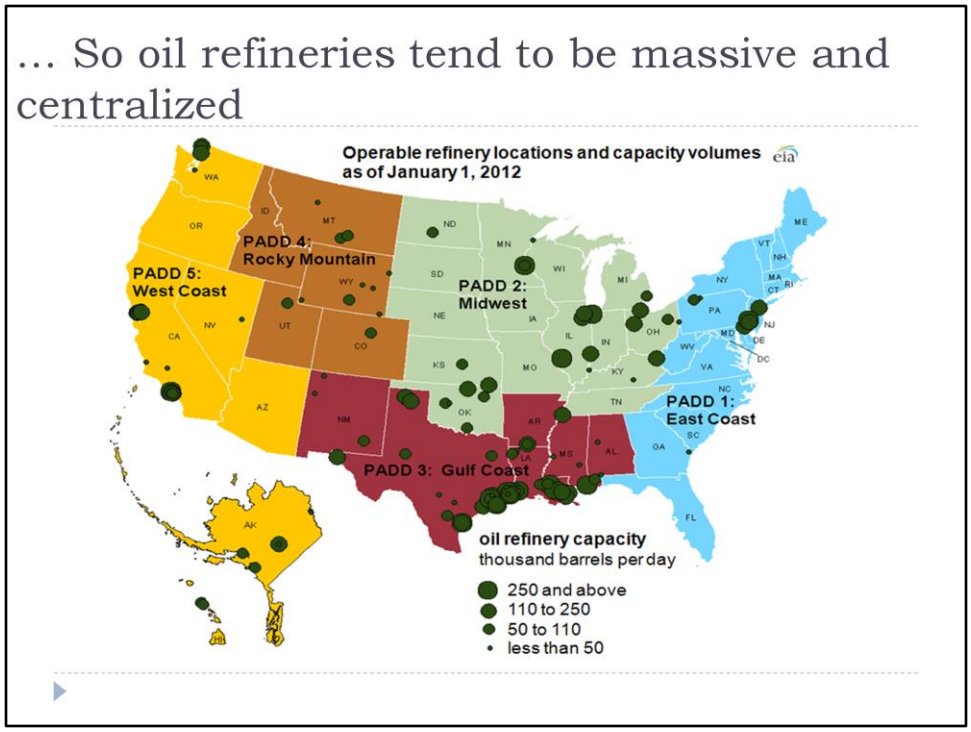
To help support this demand;

Oil is concentrated in select places in huge underground reservoirs and its pumpable ….



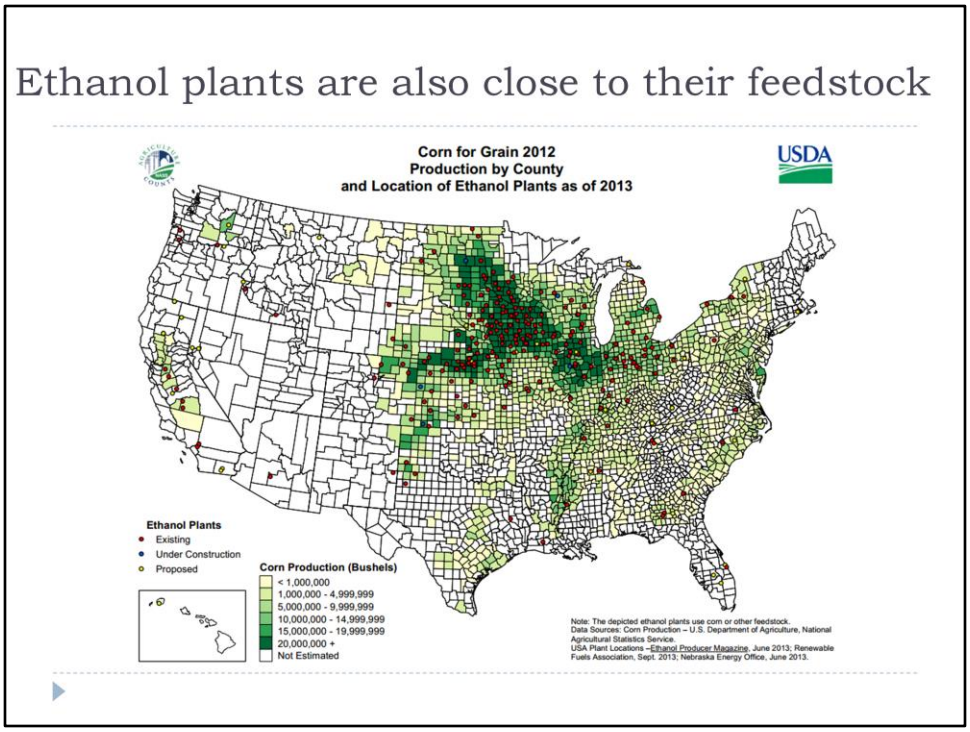
We discussed fossil fuels as a carbon source and how consolidated they are compared to biomass, but now we need to consider this in more detail because it directly relates to petroleum refining. Oil is concentrated in …..

The United States and NA are covered in biomass, not oil. The vast majority of the oil is only found in a few special areas.



Because oil is concentrated in select places in huge underground reservoirs and its pumpable, refineries tend ….

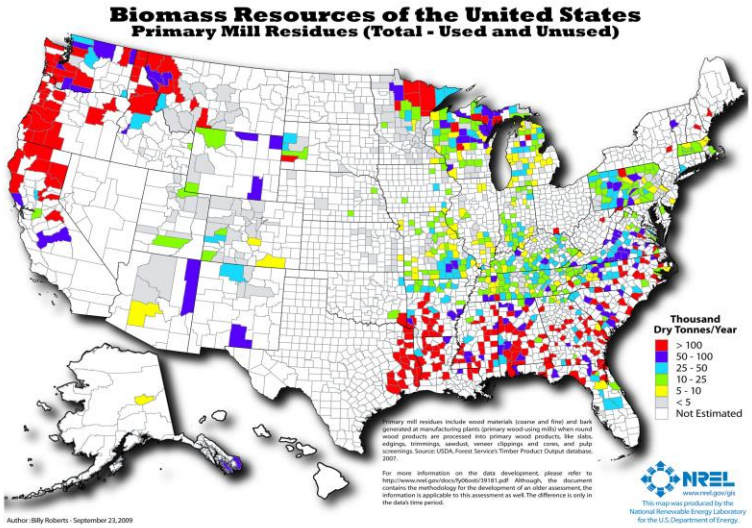
There are only ~ 150 refineries spread across the U.S. after 100 years of major oil production – these refineries fit the scale and form of their resource.



Compared to oil, there are over 200 corn ethanol plants after about 40 years of major production and the number keeps growing. Oil refining on the other hand is fairly mature and refineries are closing and consolidating instead of being built. The "newest" simple oil refinery in the United States began operating in 2008 in Wyoming. However, the newest complex refinery with significant downstream unit capacity began operating in 1977 in Louisiana.

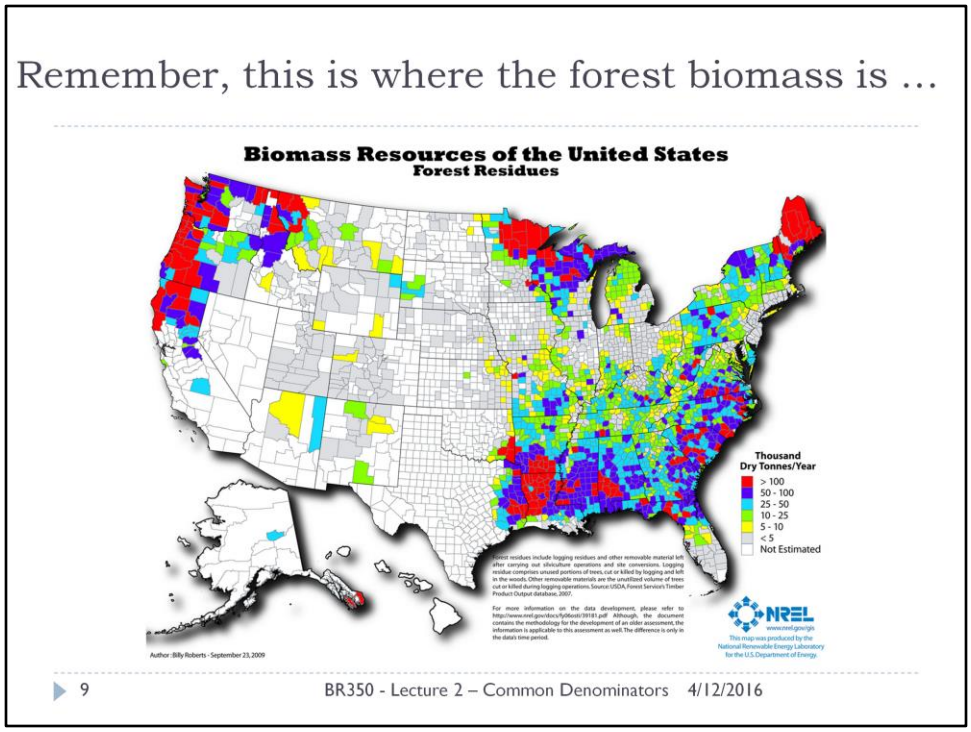
As we transition to cellulosic ethanol and new uses for ethanol broaden its markets, it is very likely that the number of ethanol and butanol refineries will expand considerably.

Biomass is found everywhere, but it's expensive to harvest and move, so wood processing for example, tends to be smaller and distributed



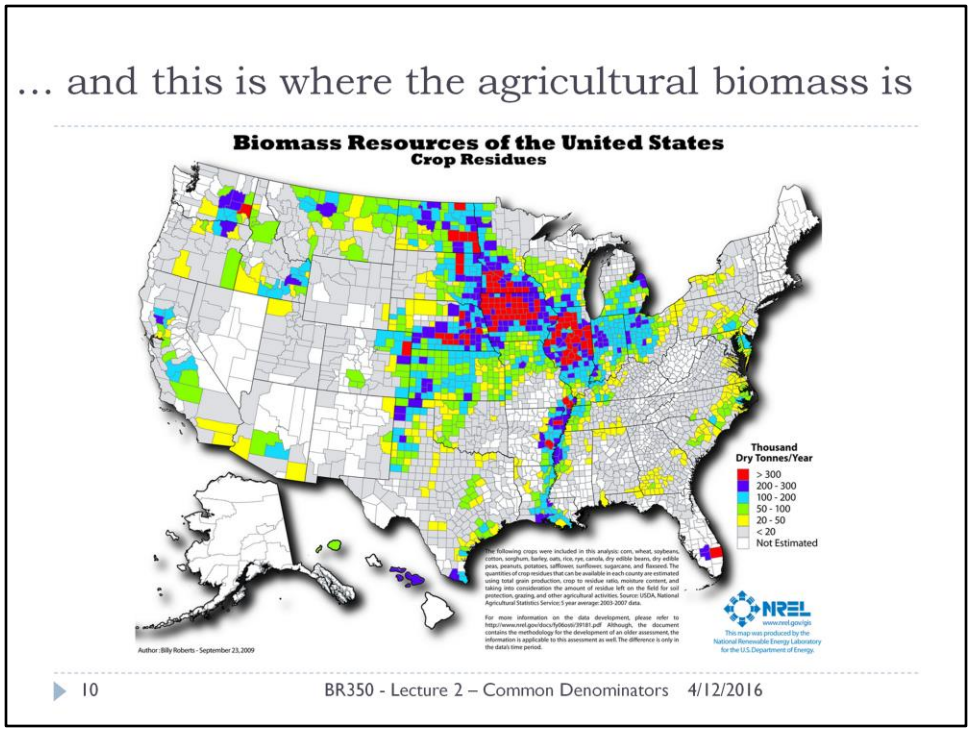
For insight into what cellulosic biorefining might look like we can consider wood processing in addition to corn farming. Biomass is found ……

There are thousands of wood processors distributed across the U.S. because of the unique aspects of processing biomass. Wood processing has been happening for longer than oil refining and where oil refining has settled on 150 facilities, wood processing has utilized thousands. This comparison makes an important statement about processing biomass for money and what is likely to be the most reasonable scale for biorefining. It does not make sense to try and build massive biorefinieis analogous to petroleum refineries because that scale doesn't fit the resource. If it did, wood processing and corn ethanol would not be as small and distributed as they are after decades and centuries of business development. To succeed, biorefiniers must fit the size and location of their resource.



…… Primarily in the PNW and the South. Minnesota, Michigan, NH, and Maine are also big forestry states.

http://www.nrel.gov/gis/biomass.html



….. Primarily in the Midwest. Everyone has some, but the Midwest really has a lot

http://www.nrel.gov/gis/biomass.html

To succeed, biorefining needs to be able to follow the wood processing model

Table 2. Projected distribution of primary biofuel producers by size

size bdtpd feedstock	number of producers	gal/day/ facility	Class aggregate million-gal/year
15	4,128	1,500	1,486
28	2,260	2,775	1,505
51	1,238	5,134	2,160
95	678	9,497	2,188
176	371	17,570	2,217
325	203	32,505	2,246
601	111	60,134	2,275
1112	61	111,248	2,305
2058	33	205,809	2,335
3807	18	380,747	2,365
Total	9,102	-	21,082

Projected Distribution by Size of 2nd Generation Primary Biofuel Producers Using a Continuous Power Function, Dr. James H. Dooley, Chief Technology Officer – Forest Concepts, LLC

This is a table from a study that assessed milk production, sawmills and all U.S. firms engaged in agricultural products. They applied a continuous power mathematical function based on these biomass products businesses to suggest the distribution by size of second generation biofuel facilities. The USDA believes that biofuels mandates can be met by building 527 biorefineries with an average capacity of 40 million gallons per year. This study refutes that idea because it means the USDA suggests that biorefineries should be based on petroleum refining and not on the businesses involved in the production of biomass products.

Their models suggest that the actual number and size of biorefineries will follow a power law distribution similar to other biomass products industries in developed nations around the globe. Depending on the scenario considered, the number of primary biofuel producers may be in the range of 4,000 to 13,000, with a most-likely number of approximately 9,000 primary producer facilities. Because this model is based on similar industries that have been using similar resources for hundreds of years, it is highly likely that this estimate is much closer to reality than the USDA's proposed 500 biorefinieres.

We cannot forget that biomass is a distributed resource and therefore it cannot be compared to oil and gas which are consolidated. This fact permeates every aspect of biorefinery planning and development and it is very likely that it will take 9,000 small biorefineires, rather than 500 massive ones.

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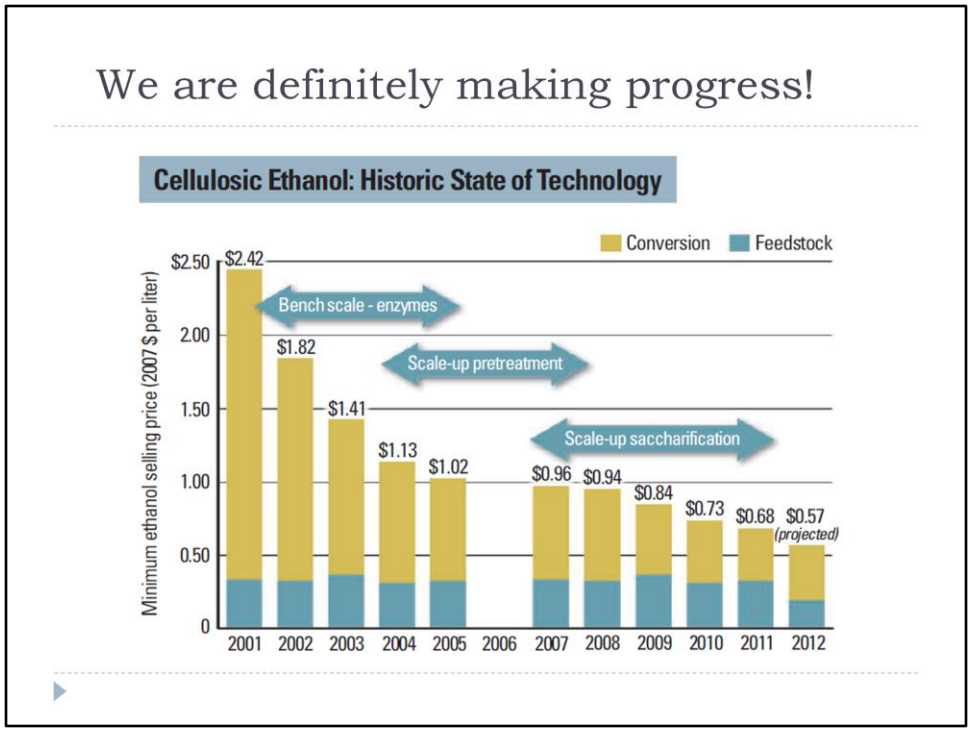
~ 84% b/w 15-50 tpd!

Projected Distribution by Size of 2nd Generation Primary Biofuel Producers Using a Continuous Power Function, Dr. James H. Dooley, Chief Technology Officer – Forest Concepts, LLC

~ 84% ….

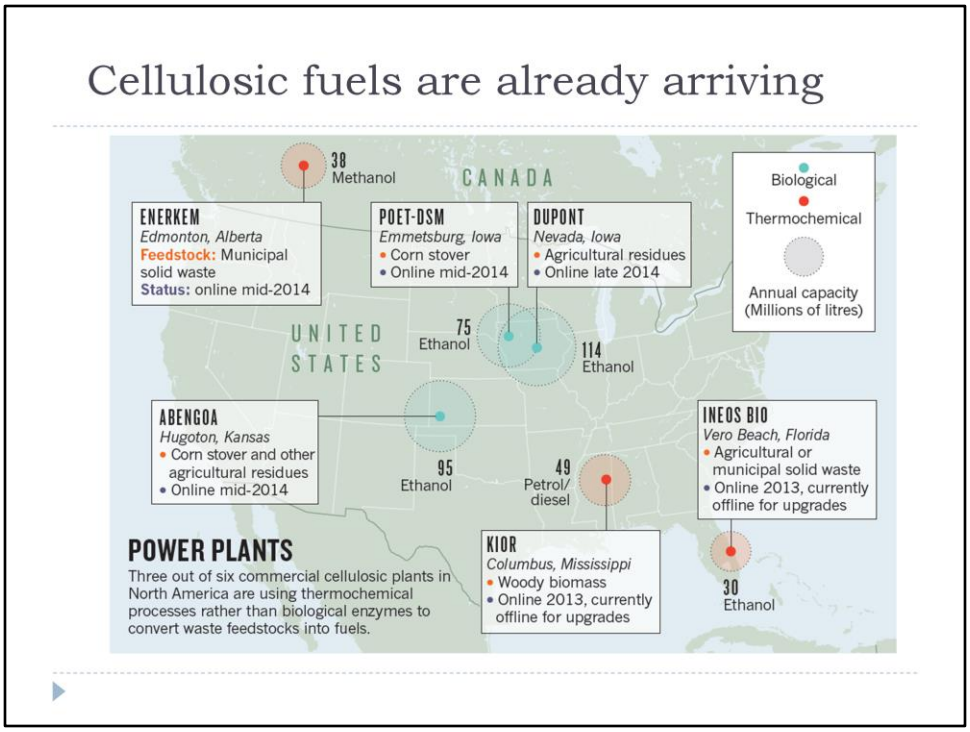
This means successfully biorefineires will need to be economic at fairly small scales … like the town or suburban scale. This also means that the choice of biomass products and markets must reflect the size of the facility. Many commodity chemicals are only commodity chemicals because they are produced at massive scales that take advantage of economy of scale. Most biorefinieres will probably not have economy of scale on their side without some form of concentrating or hub-spoke model. This is not to say that biomass couldn't be used economically for commodity chemicals, just that it couldn't be done the same way that petrochemical does it.



Battle for the Barrel, Robert F. Service, Science 22 March 2013: 339 (6126), 1374-1379.

We are ….

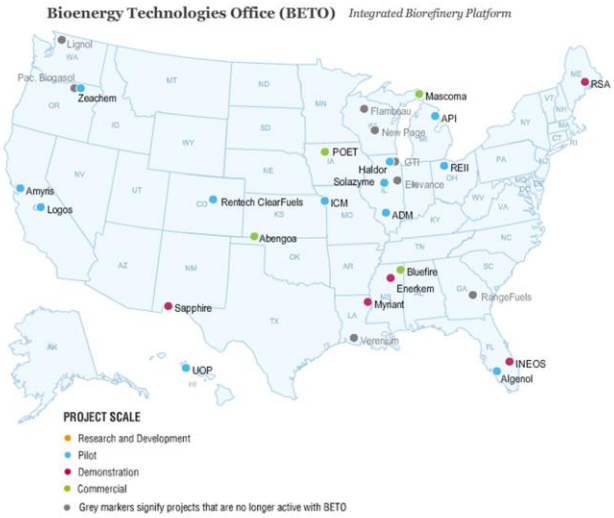
It is exciting to look at the progress of cellulosic ethanol in the last 10 years and think what the next 10 years might hold. We forget that government investment is responsible for a lot of the energy, transportation and petroleum refining infrastructure in this country and cellulosic ethanol is another good example. It takes a long time and a lot of money to get industries started and to give them a chance to succeed, but if you are persistent and there is compelling supply and demand, it will probably eventually become a reality. I believe that 30 years from now cellulosic ethanol will be recognized as just the beginning in a long stretch of commercial technological innovations that allow us to fully leverage biomass chemistries at the same levels we currently leverage hydrocarbon chemistries.



Peplow, Mark. "Cellulosic ethanol fights for life." Nature 507.7491 (2014): 152

Slowly, but surely, we are building these cellulosic ethanol facilities. Not all of them will succeed, but some will and then others will follow their success. It is also important to remember it is not just the U.S. building cellulosic ethanol facilities, but most of the developed world as well.

The U.S. continues to forge ahead in supporting these developments;



Like we discussed, there are many different biorefining platforms and though cellulosic ethanol gets a lot of press, the U.S. ….

Current and Future

- Established industries are wood pulping, corn ethanol, anaerobic digestion, and biodiesel production
- *Study of established industries will help direct future successes*

- Growing industries are cellulosic ethanol, biomass gasification, biomass pyrolysis, algae, and renewable diesel
- *Will take creativity, economics, and a focus on utilization of waste to establish these industries*

So, now to wrap this up

……read slides

Integrated Biorefineries Summary

- Integrated biorefineries use four primary conversion types; Mechanical, Thermal, Chemical, and Biological
- Integration typically means the use of more than one conversion step and attempts to reduce/utilize all waste
- Thermo-chemical conversions are generally composed of thermal and chemical conversion steps
- Bio-chemical conversions are generally composed of biological and chemical conversion steps
- Biorefineries are not the answer to oil or coal, they are a way to make better use of our biomass
- Small biorefineries make more sense than large ones because they need to use biomass
- Biorefining is not a mature industry and there will be more failures alongside any new successes. LOTS of promise, but LOTS of risk as well

Please take a moment and review

Next Lecture – USA Fuel Paradigm

http://www.nytimes.com/2013/10/21/business/whats-that-smell-exotic-scents-made-from-re-engineered-yeast.html?pagewanted=all
http://www.allylix.com/
http://www.amyris.com/
http://bluemarblebio.com/

When you have an opportunity please visit some of the attached links. They are for companies that are making high valued biomass chemicals at small-medium scales that fit the biomass resource well. These are specialty and fine chemicals that don't have enormous markets, but they are quite expensive and making them in a biorefinery has the potential to be much cheaper/easier than what we have been doing. At least initially this model fits biomass well, and these companies are likely to succeed if they can continue innovating and balancing their product offerings with their resource and the market demands. If they do indeed become successful, highly profitable companies they will represent a model that others can follow.