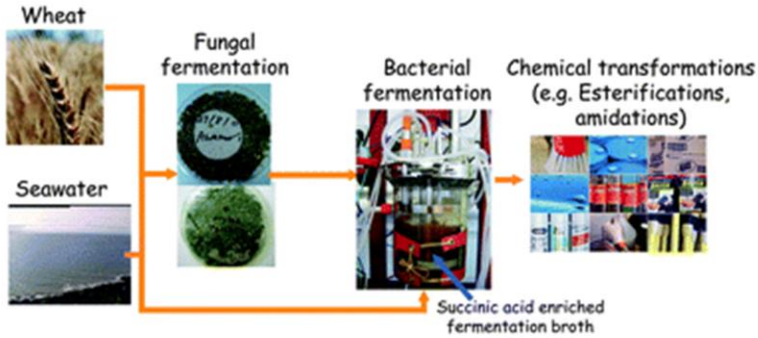


Biorefining

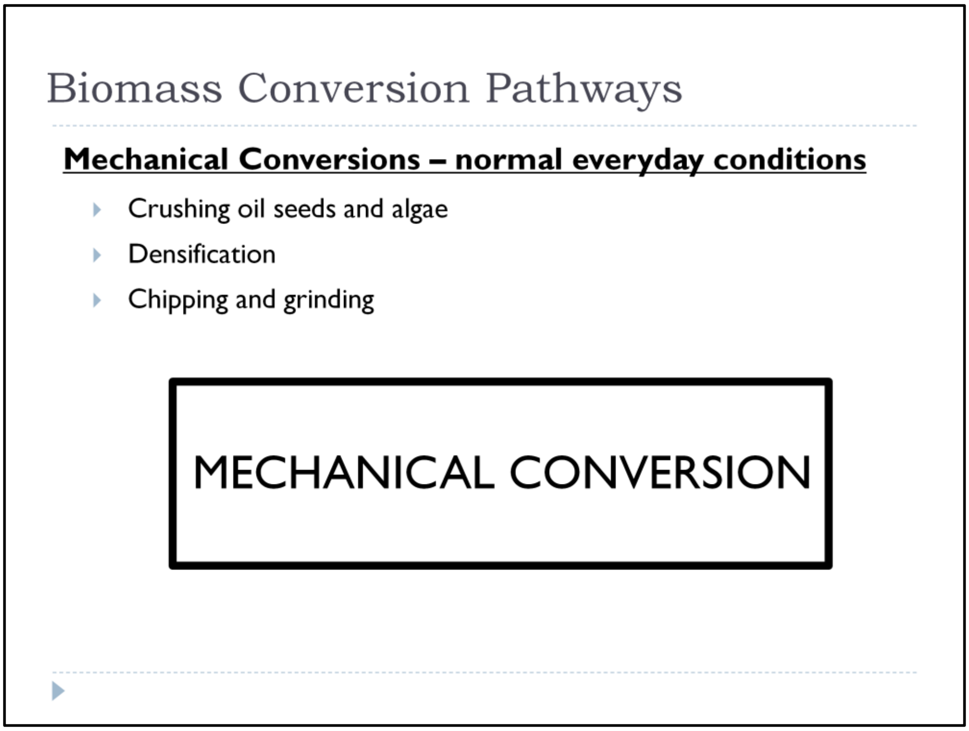
Lecture 18 – Integrated Biorefineries

Lin, Carol SK, et al. "A seawater-based biorefining strategy for fermentative production and chemical transformations of succinic acid." Energy & Environmental Science 4.4 (2011): 1471-1479.

This is the lecture where we put it all together, but before we do, I would like you to take a moment and think about seawater. Bioenergy uses a lot of water to grow biomass and then a lot of water to convert that biomass into the things we want. So, an important area of development for future biorefineries will be using processes that can take advantage of seawater instead of freshwater. There isn't too much out there right now, but you can be sure that processes that can use seawater are probably going to be more economical and sustainable than the ones that need freshwater. This is a something 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



Most bioenergy ideas and businesses use combinations of different conversion processes and then come up with a cool name for it that gets attention.

When someone tells you about a bioenergy conversion process you need to be able to identify the basic parts. There are generally only four basic possibilities; and mechanical conversions, thermal conversions, chemical conversions and biological conversions.

Almost every known bioenergy process will fall into one or more of these categories. You will not be responsible for understanding all of the various details of each conversion type, but you will be responsible for developing a basic understanding that allows you identify them when evaluating bioenergy news and developments.

We have just spent the last few weeks learning about these four different pathways. Now we are going to put them together into a biorefinery. First there were mechanical conversions. Please take a moment to remember what these are.

Biomass Conversion Pathways

Thermal Conversions – over 400 ˚C

- Combustion (excess oxygen produces excess heat)
- Pyrolysis (heat with no oxygen)
- Gasification (heat with some oxygen)

THERMAL CONVERSION

Then thermal conversions. Please take a moment to remember what these are.

Biomass Conversion Pathways

Chemical Conversions – under 400 °C

- Step 1: Biomass breakdown to components
- Step 2: Biomass components converted to fuels & chemicals
- Oil and Syngas Conversions

CHEMICAL CONVERSION

Then chemical conversions. Please take a moment to remember what these are.

Biomass Conversion Pathways

Biological Conversions – under 100 °C

- Process 1: Fermentations/anaerobic digestion (feeding microbes to make chemicals)
- Process 2: Photosynthetic organisms and animals

BIOLOGICAL CONVERSION

Then biological conversions. Please take a moment to remember what these are.

"**INTEGRATED** BIOREFINERY"

- Integration typically means the use of more than one conversion or step
- A primary goal of integration is the reduction of waste and/or the utilization of all waste

The forest products industry and the petroleum industry are excellent examples of "integration"

An integrated biorefinery is just what is says, it is an integrated biorefinery

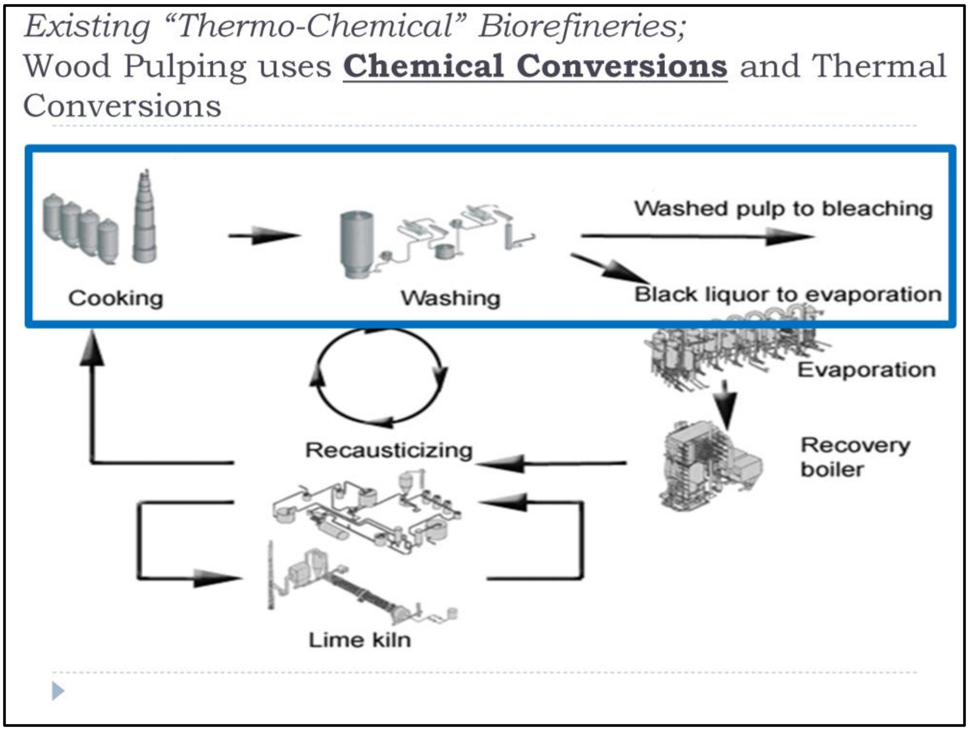
Read slide.

"INTEGRATED **BIOREFINERY**"

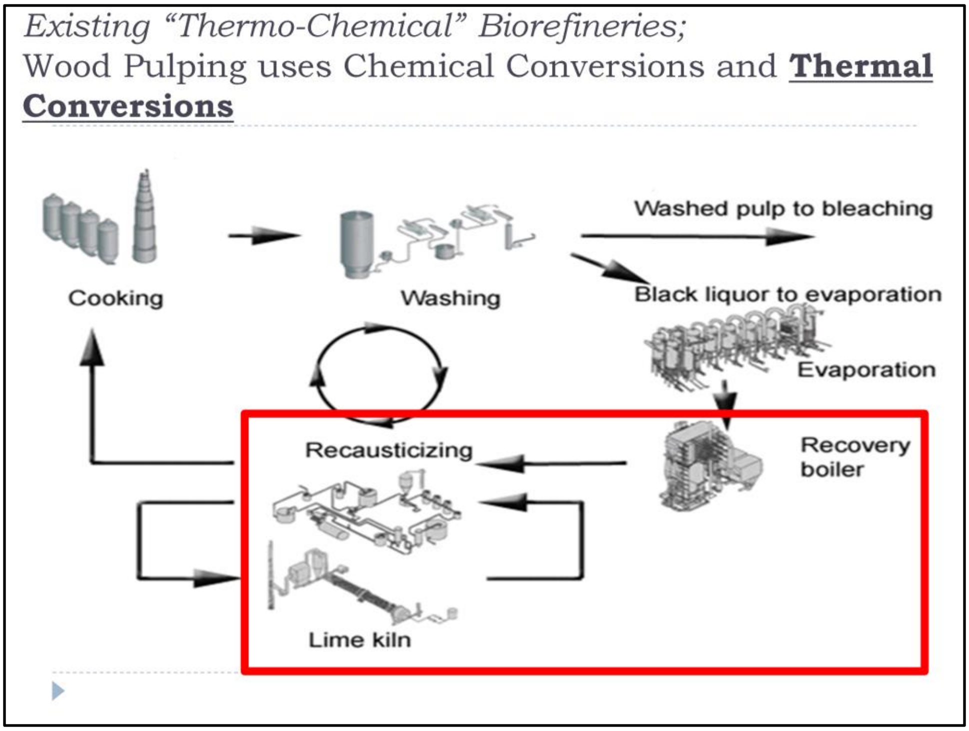
- Biorefinery typically defines a facility that converts biomass into various chemical products
- Consider "bio" to be biomass and "refining" to mean breaking it down into something and capturing products of interest

Wood pulping, biodiesel production, and anaerobic digesters can all be considered "biorefining" industries

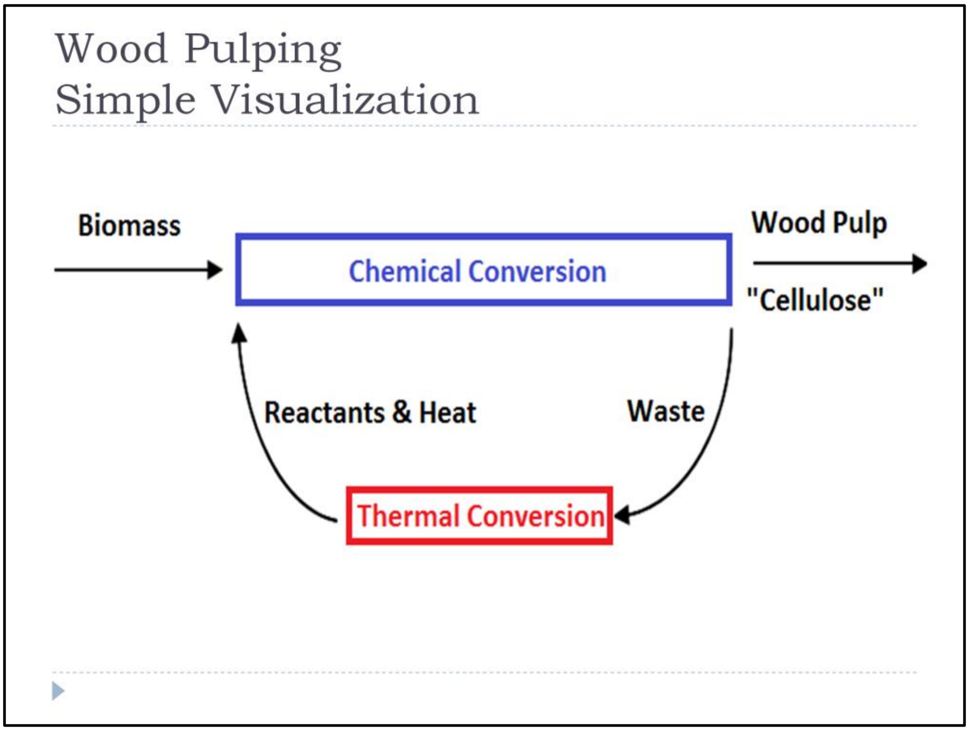
Read slide



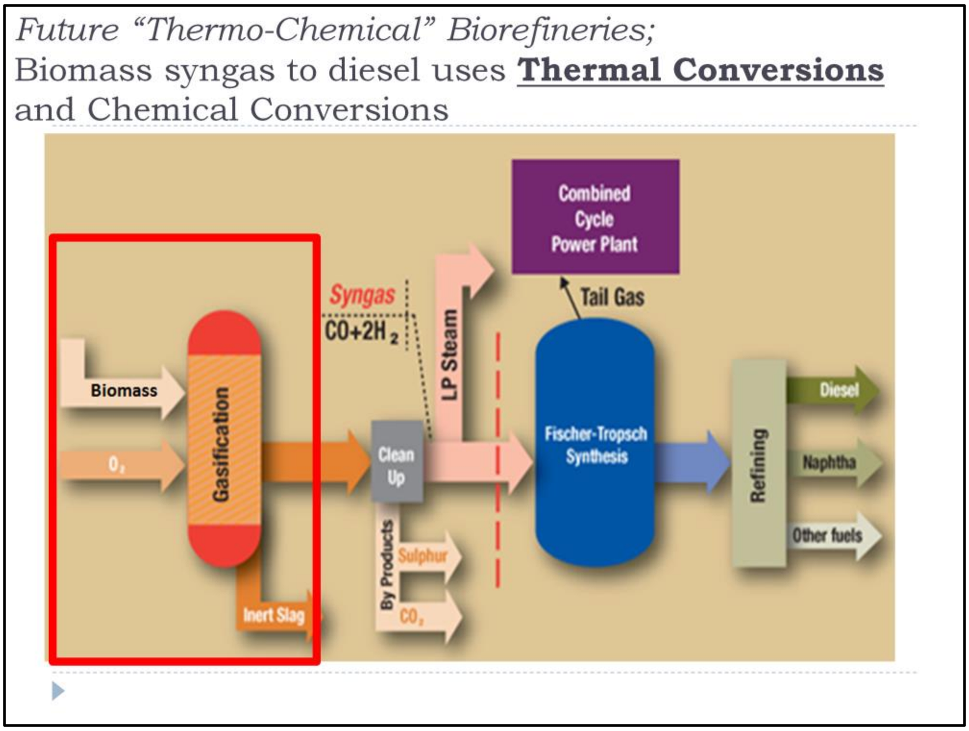
We will start with wood pulping because it is an existing integrated biorefinery. You have seen this diagram before. It shows the approximate wood pulping process. Wood pulping integrates chemical conversions roughly shown inside blue square.



With thermal conversions shown inside the red square.



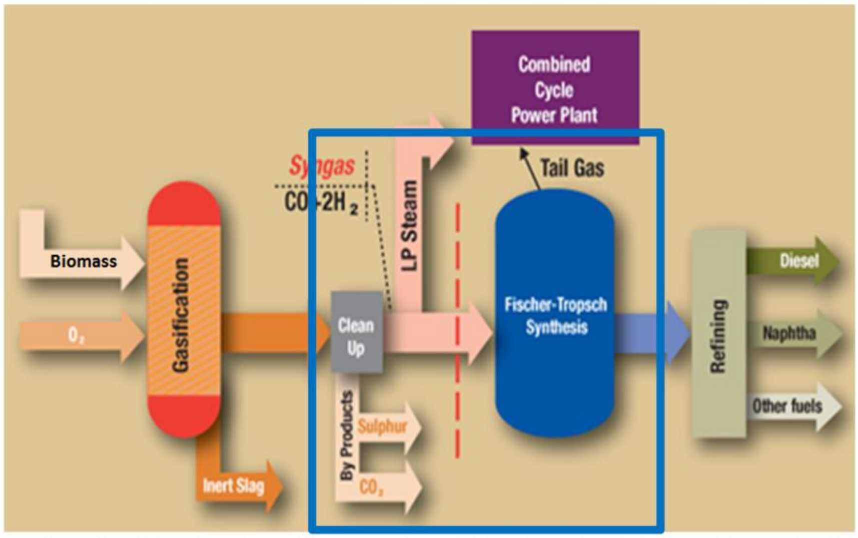
Now, if we take away the process diagram and just think about what we have learned about the conversions, it looks like this. It is really quite simple and much easier to visualize when you think about it like this. So let's try another process.



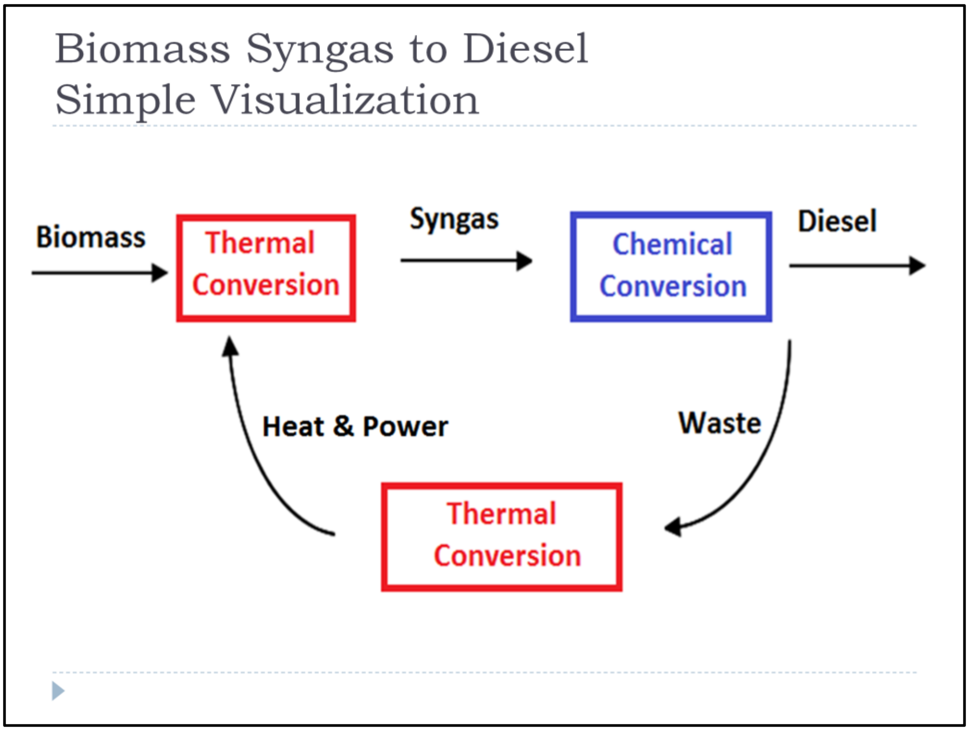
Now we will look at an upcoming style of integrated biorefinery similar to the first cellulosic ethanol plant. This diagram shows the approximate biomass to Fischer Tropsch diesel process. Biomass to FT integrates thermal conversions roughly shown inside red square.

Future "Thermo-Chemical" Biorefineries;

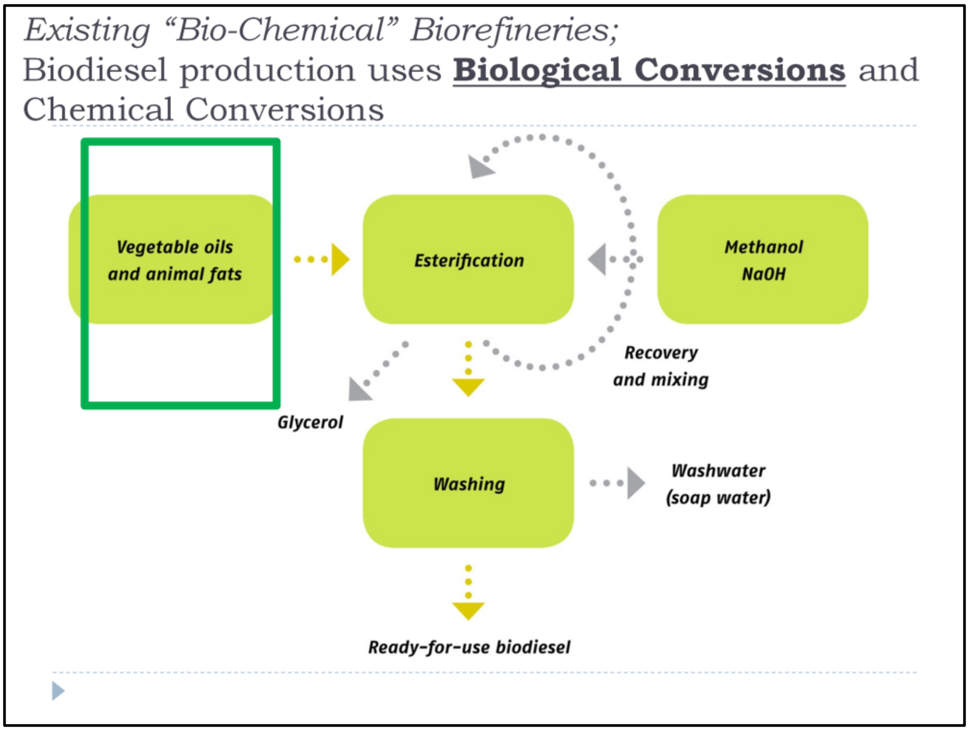
Biomass syngas to diesel uses Thermal Conversions and **Chemical Conversions**



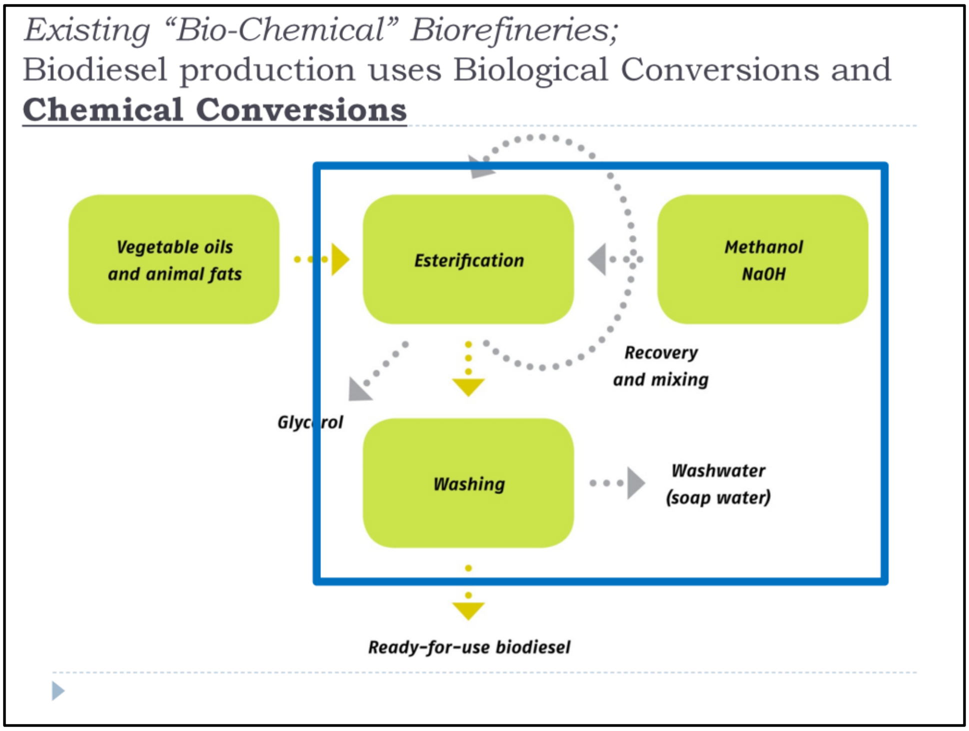
With chemical conversions shown inside the blue square.



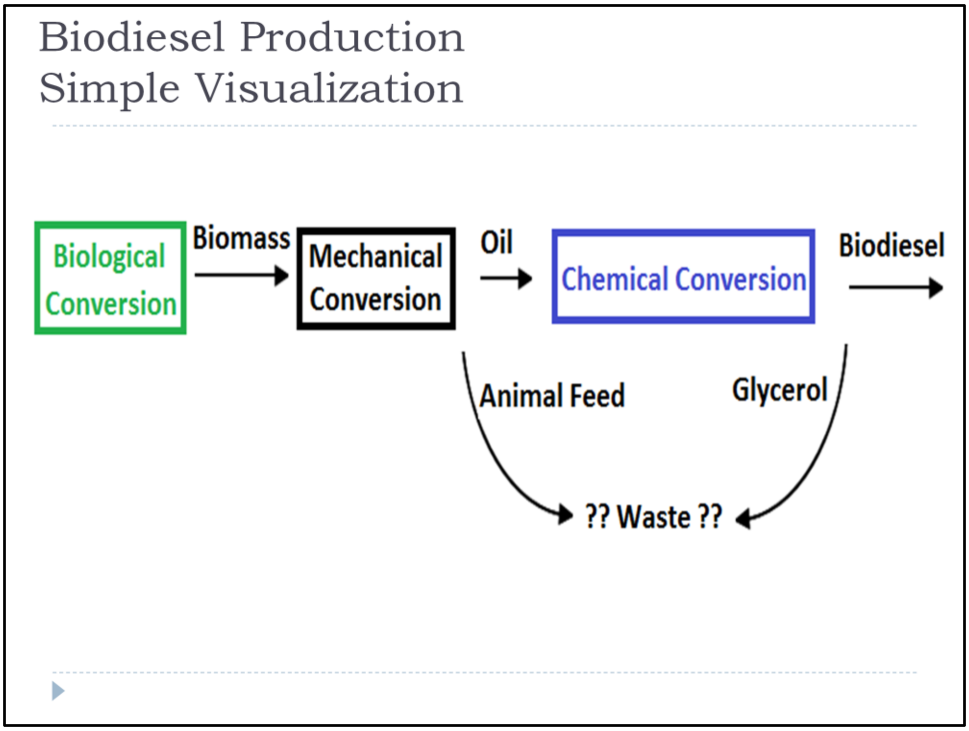
Now, if we take away the process diagram and just think about what we have learned about the conversions, it looks like this. Again, it is really quite simple and much easier to visualize when you think about it like this. So let's try a couple more.



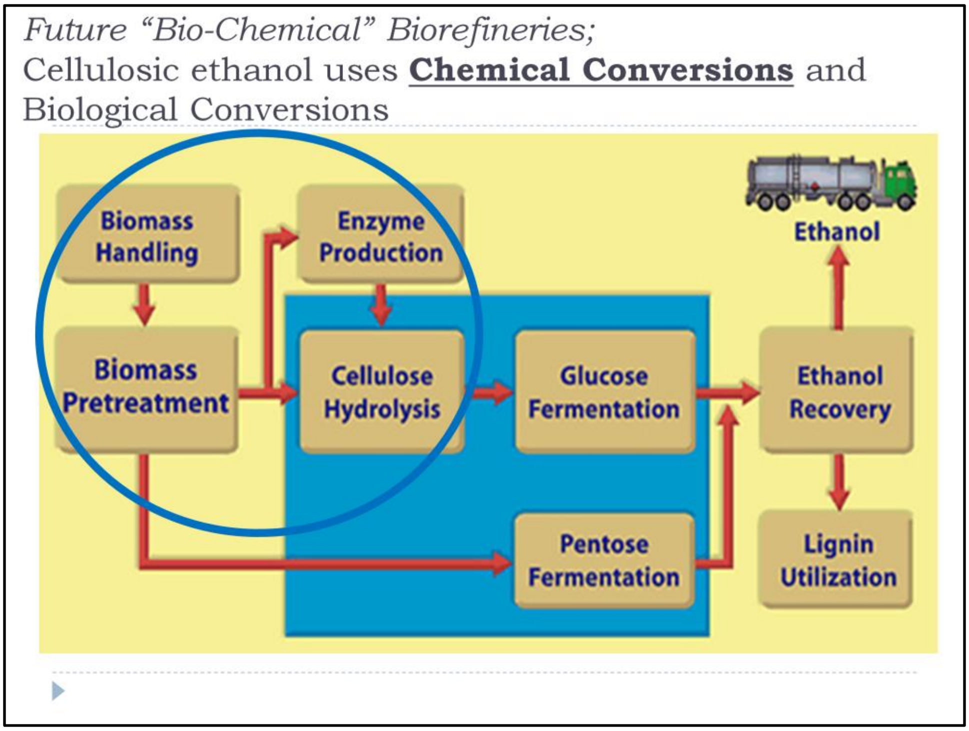
You have seen this diagram before and it shows the approximate biodiesel process minus the mechanical conversion. Biodiesel integrates biological conversions roughly shown inside green square.



With chemical conversions shown inside the blue square.

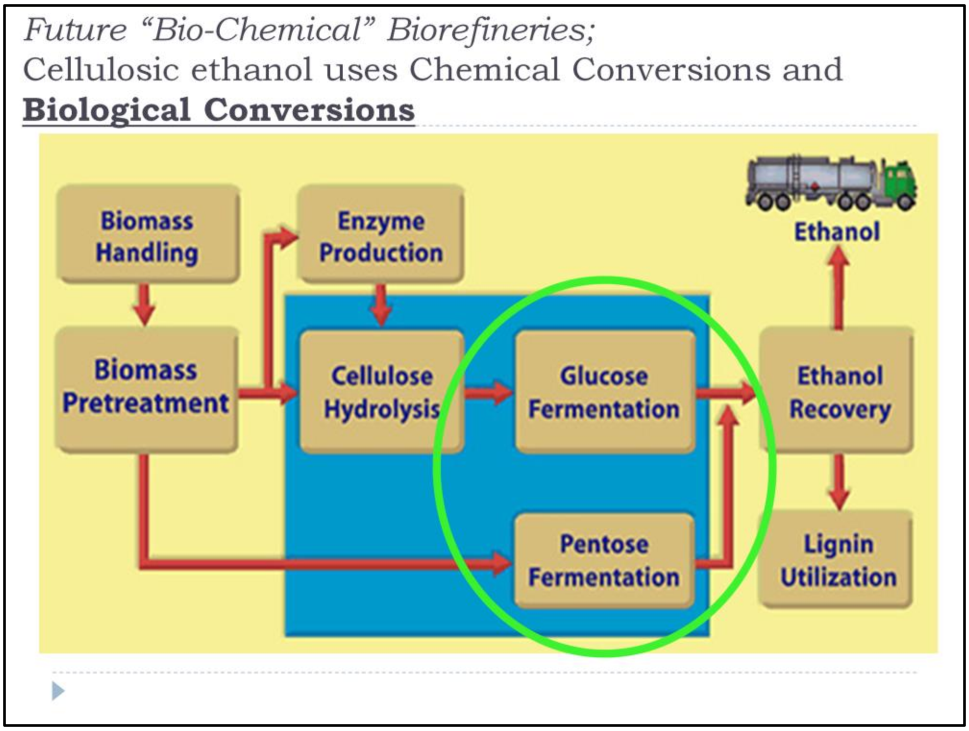


Now, if we take away the process diagram and just think about what we have learned about the conversions, it looks like this. Notice how this simple visualization contains a mechanical step that wasn't shown in a highlighted box in the previous slides. That is not because it wasn't necessary, it is because the diagram didn't even bother to show it. You have to be able to not only read the diagrams, but also think about them because they often don't tell the whole story. The waste from biodiesel is another aspect of this. For some operations it is a waste and for some it is a product, but it's always there regardless of whether or not it gets used.



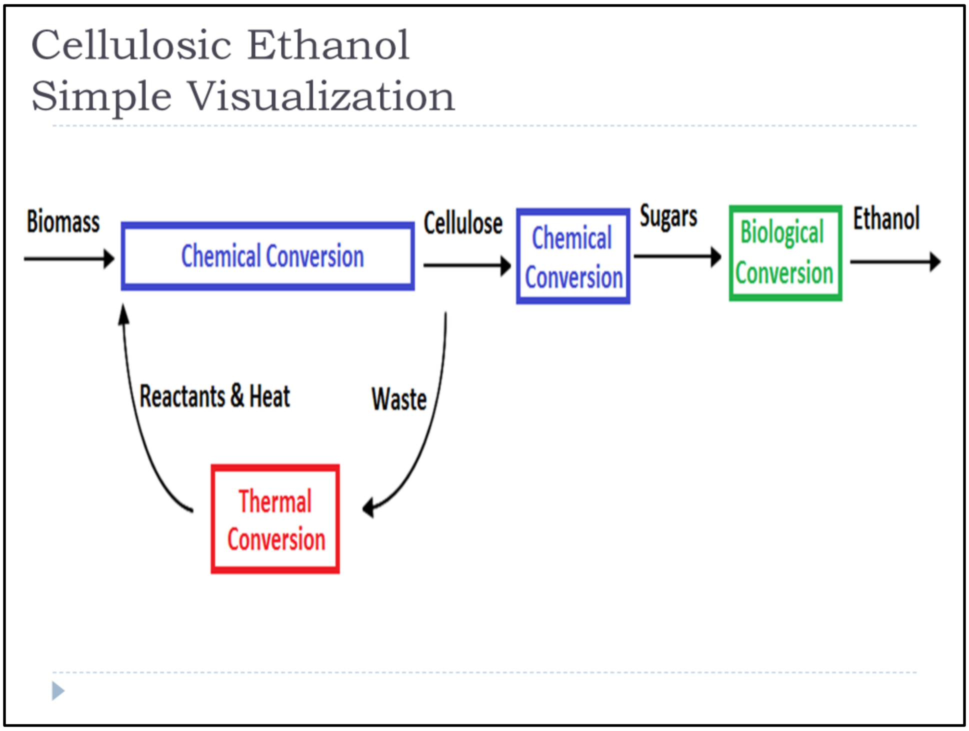
http://www.ethanolrfa.org/resource/cellulosic/

This diagram shows the approximate traditional cellulosic ethanol process. Cellulosic ethanol integrates chemical conversions roughly shown inside blue circle.



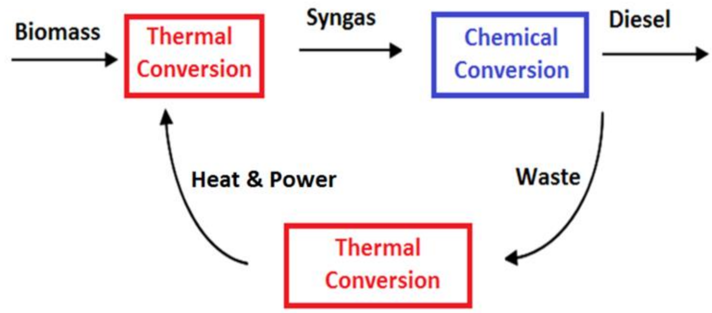
http://www.ethanolrfa.org/resource/cellulosic/

Whith biological conversions shown inside the green circle.



Now, if we take away the process diagram and just think about what we have learned about the conversions, it looks like this. This simplification is interesting because it makes you realize how complicated cellulosic ethanol can be and how integrated it really is.

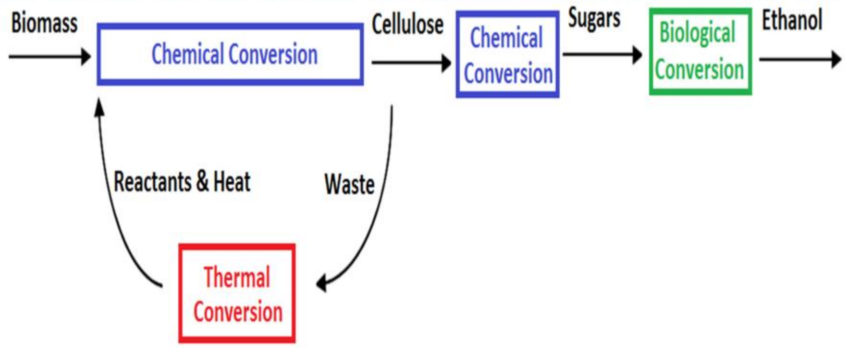
No clear winners or losers based on conversion efficiency



- ~ 90% conversion biomass to syngas
- ~ 50% syngas is CO and H2
- ~ 60% conversion syngas to diesel
- **Overall mass conversion ~ 27%**

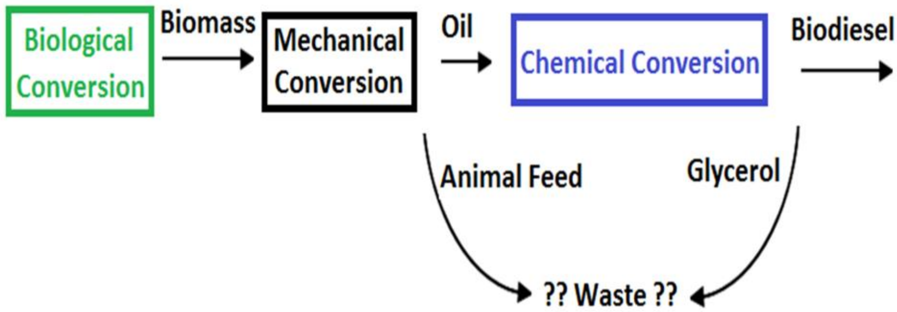
Read slide

No clear winners or losers based on conversion efficiency



- ~ 50% conversion biomass to cellulose
- ~ 95% conversion cellulose to sugars
- ~ 50% conversion sugars to ethanol
- **Overall mass conversion ~ 24%**

No clear winners or losers based on conversion efficiency



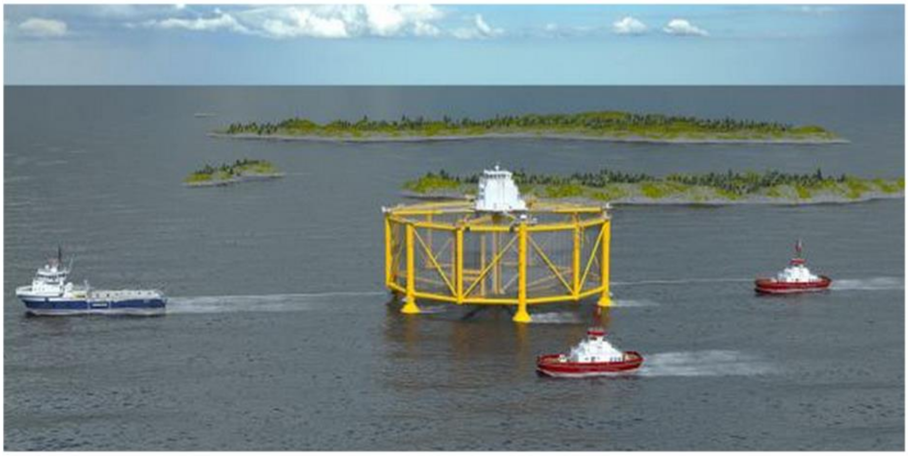
- ~ 20% conversion biomass to oil
- ~ 83% conversion oil to biodiesel
- **Overall mass conversion ~ 17%**

General things to remember

- Thermal conversions are good for making mixed products and heat
- Chemical conversions are good for making high purity products
- Biological conversions are good for producing products difficult to synthesize
- Thermal is the hammer, chemical is the knife, and biological is the aquarium

Read slide

Next Lecture – Biorefining in North America



25 BR350 - Lecture 2 – Common Denominators 4/12/2016

http://www.dailymail.co.uk/sciencetech/article-2575030/The-automated-fish-rigs-farm-Salmon-North-Sea.html
http://thinkprogress.org/climate/2014/04/21/3422486/big-ag-takes-to-the-ocean/

We started this lecture talking about seawater and we are going to wrap up thinking about ocean farming. When you have a chance please visit the attached links that discuss new efforts in Europe and Australia to build fish farms using offshore oil rig technology and methods. Algae get such high yields per acre because they are grown in water. They can take advantage of vertical space in a way that terrestrial plants can't. The more vertical space you can take advantage of the smaller your footprint is and the easier it is to manage things. So, learning how to cultivate successfully in deep ocean waters offshore has some interesting aspects that could also be paradigm changers for how the world grows its biomass in the future – worth considering.