BIOMASS ENERGY TRAINING CURRICULUM

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This curriculum was developed through a Southern SARE grant and collaboration between Tennessee State University, the University of Tennessee, eXtension.org, and USDA-Rural Development. The objective of this curriculum is to provide training on biomass energy to extension agents and local officials so that they may deliver this information to their stakeholders.

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Biomass Energy Training Curriculum

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Funding was provided through the Southern Sustainable Agriculture Research and Education (SARE) Program

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This curriculum and supporting documents can be accessed

online (in full and as separate modules) at

http://articles.extension.org/pages/73919

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Part I: Introduction to Biomass Energy

Biofuel feedstocks

Learning objectives:

- Participants will be able to identify different biofuel crops.
- Participants will be able to describe how biofuels are produced.
- Participants will be able to state the advantages and disadvantages of various biofuel crops.

Materials:

- PowerPoint® slides "Biofuel feedstocks"
- Lesson guide: Use the notes in this lesson guide to present information for each presentation slide.
- Factsheet: "Agricultural feedstocks for cellulosic ethanol and biodiesel" http://www.tnstate.edu/extension/documents/Feedstocks.pdf A copy can also be found in the Appendix.
- Questions found at the end of this lesson guide can be used to test participants' knowledge at the end of the presentation. This can be combined with clickers to improve audience engagement and create discussion.
- An evaluation of the presentation can be found in this lesson guide following the lesson questions.

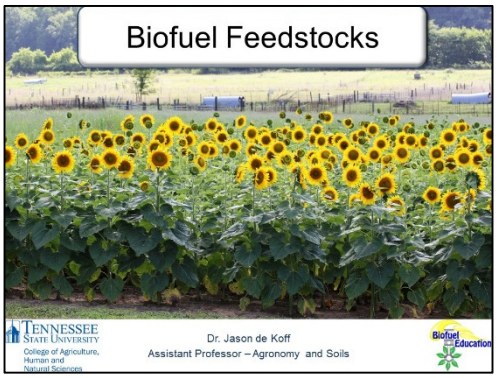
Topics:

Renewable fuels standard
Biofuel conversion processes
Fuel comparisons
Cellulosic ethanol feedstocks
Biodiesel feedstocks

If time allows, show video clip "How Can We Divert Lost Land to Biofuels"
http://www.switchenergyproject.com/topics/biofuels

Slide 1

In this presentation, we will talk about some of the basics of biofuels production and some of the different types of crops (feedstocks) that can be used to produce biofuels.



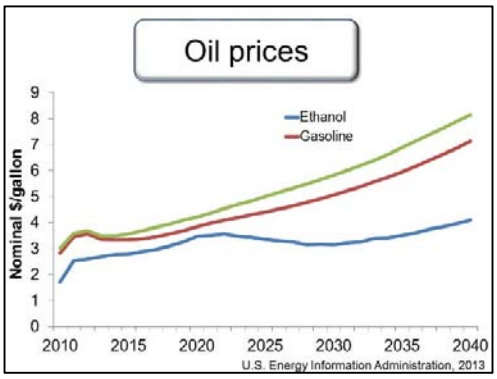
Slide 1

Slide 2

Oil prices will continue to rise while ethanol prices will remain relatively constant at $2/gallon

China and developing nations will continue to consume more fossil fuels and prices will increase, even if flow is maintained at current rates (depicted in graph).

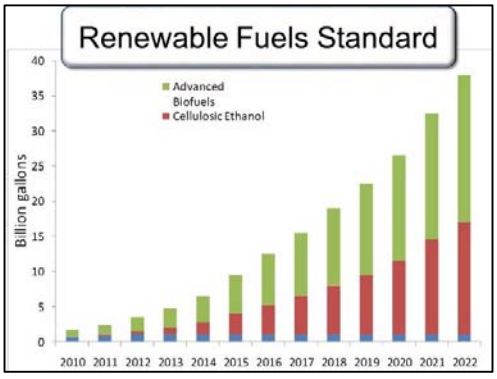
Therefore, it is important to come up with alternative strategies that can be implemented now.



Slide 2

Slide 3

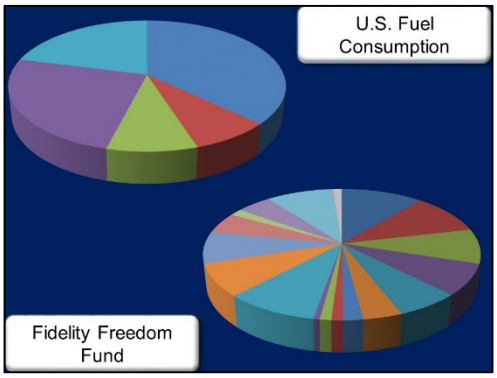
The Renewable Fuels Standard is a mandate established by the federal government to help create an incentive for biofuel production. This mandate requires increasing amounts of biofuels to be used for transportation fuels. It is expected that by 2022, about 36 billion gallons of transportation fuel will come from biofuels each year. This is expected to decrease oil imports by $41.5 billion by 2022. Cellulosic ethanol and advanced biofuels use are mandated to increase over time (even if it has to be imported). Advanced biofuels are those that rely on newer technology and may also include biodiesel production.



Slide 3

Slide 4

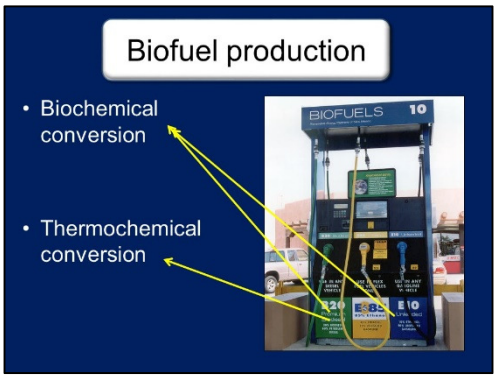
U.S. fuel consumption is dominated by fossil fuels at 83% of total consumption (37% Petroleum, 25% Natural Gas, 21% Coal) with nuclear energy at 9% and renewable energy at 8%. To manage risk involved in the volatility of this market, it is important to diversify our energy sources. When we manage risk we can look to something like a retirement plan which shows the number of sources involved to prevent major risks from having a significant impact.



Slide 4

Slide 5

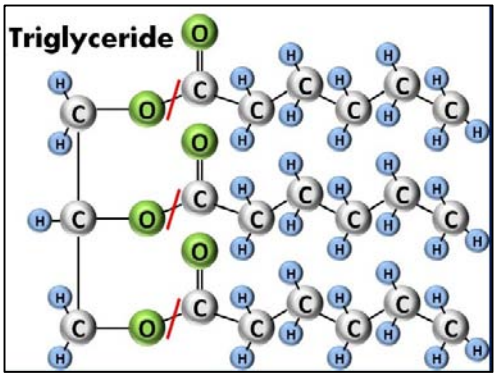
Producing biofuels requires different types of conversion pathways depending on the type of fuel being produced. Biochemical conversion is used to produce cellulosic ethanol. Thermochemical conversion is used to produce energy through combustion (heat energy), gasification (gases), pyrolysis (biodiesel). A chemical conversion process can also be used to produce biodiesel.



Slide 5

Slide 6

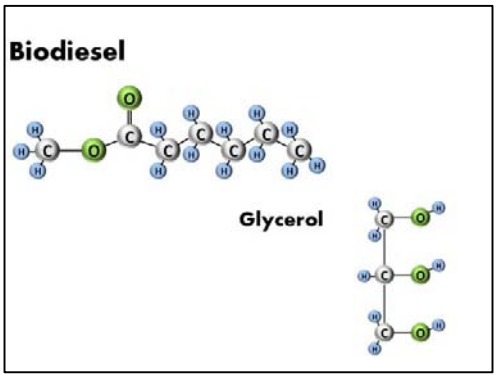
To begin, we'll explain the chemical conversion process involved in producing biodiesel. This process is called transesterification. Vegetable oils and animal fats are primarily triglycerides which contain three fatty acids that are esters and one glycerol molecule. These triglycerides are large bulky molecules and the oils are usually thicker than regular diesel that is normally used for fuel in a diesel engine. Therefore, we have to break apart this molecule to create a thinner product. The triglyceride reacts with the alcohol (usually methanol), the alcohol removes the glycerol molecule and creates three esters that are methyl or ethyl esters (depending on the alcohol used). The slide shows how the molecule is broken apart. A chemical catalyst (usually sodium or potassium hydroxide) similar to lye is also used to help break apart the oil molecules.



Slide 6

Slide 7

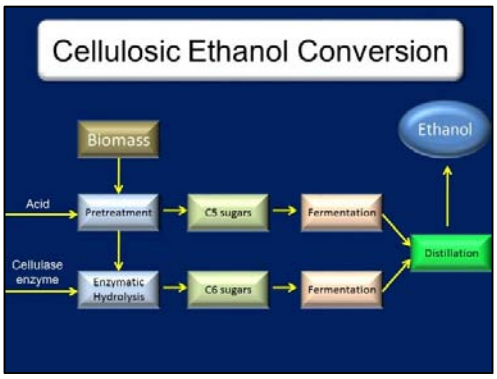
The final products are the methyl or ethyl esters that are created (biodiesel) and the glycerol. Glycerol is used to make soap, paints, resins.



Slide 7

Slide 8

The cellulosic ethanol process is very similar to the process used in making corn ethanol but it requires an extra step. You can tell the sugars that are readily available in corn which makes it easy to ferment them into ethanol and purify it through distillation. With a cellulosic material like wood or switchgrass, the sugars are mostly in the form of cellulose and hemicellulose and are not readily available. A pretreatment step with dilute acid is used to hydrolyze hemicellulose and make the cellulose more accessible to hydrolysis by enzymes.



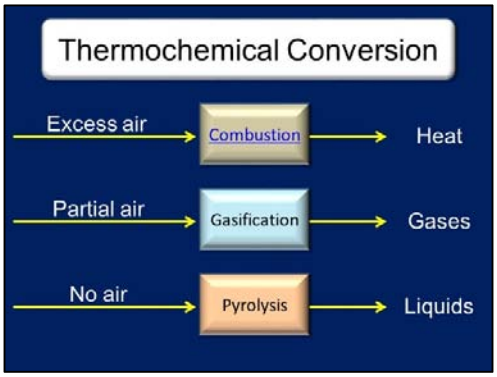
Slide 8

A few years ago, 60 farmers in East TN were contracted to grow switchgrass within a 50 mile radius of a pilot plant. They are still working on the getting this process to be commercially viable.

If time allows show an introduction video on ethanol research "Future Green: New Biofuel Crops":
http://www.switchenergyproject.com/topics/energysitevisits#energy-site-future-green-new-biofuels-crops

Slide 9

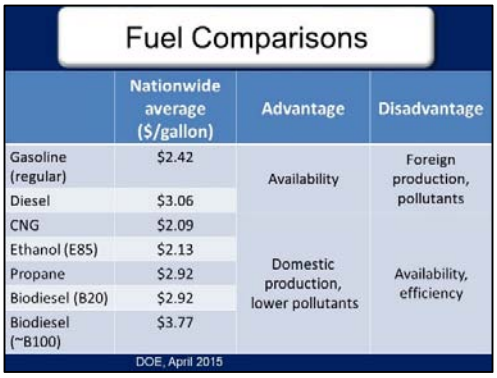
For the thermochemical conversion processes, the mainly differ by the amount of oxygen that is allowed in the system. Combustion is the most basic that we can all relate to. You light a fire and you have combustion which produces heat energy. This type of process is used in power plants to produce electricity. With lower amounts of oxygen present we can have gasification which produces syngases like hydrogen that can be burned to produce electricity. Pyrolysis allows no oxygen into the system and produces oils similar to crude that can be refined to biodiesel.



Slide 9

Slide 10

This slide shows some price comparisons of different fuel sources from 2015. Blends with ethanol or biodiesel are relatively comparable in price. Some of the advantages of fossil fuels include their availability, there is a well-established infrastructure for extracting and converting these into fuels. However, the disadvantage is that we rely on foreign production for our petroleum products which can affect our national and economic security.

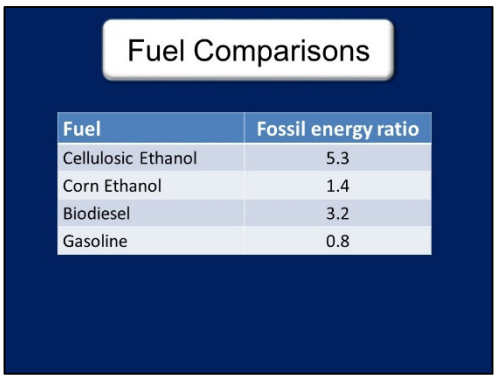


Slide 10

The efficiency of ethanol when burned as a fuel can be made up by __lower prices__ at the pump.

Slide 11

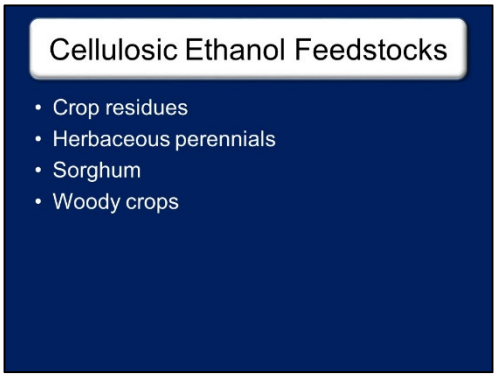
We can also compare fuels by their energy efficiency. This is called the fossil energy ratio which is a ratio of the energy output of the final biofuel product compared to the fossil energy necessary to produce the biofuel. Less than one means it is not energy efficient to produce….5.3 for cellulosic ethanol, 3.2 for biodiesel, 1.4 for corn ethanol, 0.8 for gasoline (Sheehan and Wang, 2003). It is also estimated that bioenergy from canola has a fossil energy ratio of 2.5 and ethanol from sugarcane has a fossil energy ratio of 8 (National Geographic, 2008).



Slide 11

Slide 12

Now we will get into the different types of feedstocks that can be used for producing either cellulosic ethanol or biodiesel. For cellulosic ethanol, all you need is a material that grows quickly and produces a lot of cellulosic biomass. Some of the most important ones include crop residues, herbaceous perennials, sorghum and woody crops.



Slide 12

Slide 13

Corn stover is the material that is left of the field after a corn harvest. It is the largest untapped resource in the U.S. but other crops residues could contribute, like sugarcane bagasse and hay from seed production. There is some concern about removing too much of this material because it could adversely affect erosion, soil organic matter or soil nutrients or biota. The amount that can be removed is dependent upon things like location and soil type. A study performed in the SE U.S. found that 1.3 to 3.1 tons/acre could be harvested as long as conservation tillage was utilized (Karlen et al., 1984, Braun et al., 2011).

Slide 13

Slide 14

Herbaceous perennials include switchgrass, miscanthus, alfalfa, native polycultures (big bluestem, little bluestem, indiangrass), sugar cane, energy cane. Mitchell et al. (2008) identified 4 advantages to using herbaceous perennials over annual row crops:

1. No annual establishment requirements (lower economic/energy inputs)
2. Fewer chemical inputs (pesticide/fertilizer)
3. Produce large quantities of biomass
4. Ecosystem services (soil stabilization, soil carbon sequestration, wildlife habitat)

Slide 14

Slide 15

This slide shows a comparison between different herbaceous perennials based on a number of different factors. The "-" indicates that these are not as good for these categories while the "+" and "++" indicate good properties.

Mitchell, 2011	Switchgrass	Native Polyculture	Miscanthus	Alfalfa	Sugar Cane
Native	+	+	-	-	-
Yield Potential	+	+(-)	++	+	++
N fertilizer	-	-	++	+	-
Rapid Establishment	+	+	-	+	-
Producer Experience	+	+	-	++	++
Field Scale	+	+		++	++
Ecosystem Services	++	+	+	+	+
Alternate Use	+	+	-	++	+
Multiple Conversion Forms	-	-	-	-	++

Slide 15

Slide 16

In finding ways to reduce competition with food crops, it is important to find areas where these feedstocks can be grown. Many native grasses can be grown on marginal land that is less fertile than cropland. In places like the Great Plains that use a lot of center pivot irrigation, these grasses could be grown in the nonirrigated corners. It is estimated that this could produce enough biomass to supply a 50 million gallon cellulosic ethanol plant.

Slide 16

Slide 17

Sorghum is an annual tropical grass that can be grown in a number of different climates.

Slide 17

There are actually 4 different types of sorghum: sweet, forage, high-tonnage and grain. Like the perennial grasses, sorghum can increase soil carbon due to their deep root system, they can grow in a range of soils, and can serve as an additional food source for livestock.

Sweet sorghum requires less water and contains higher fermentable sugars than corn. Ethanol production is similar to that of sugarcane. Under favorable conditions, it can produce over 800 gallons per acre. The remaining residue could be used for conversion to cellulosic ethanol. Juice extraction must be done right away to avoid degradation.

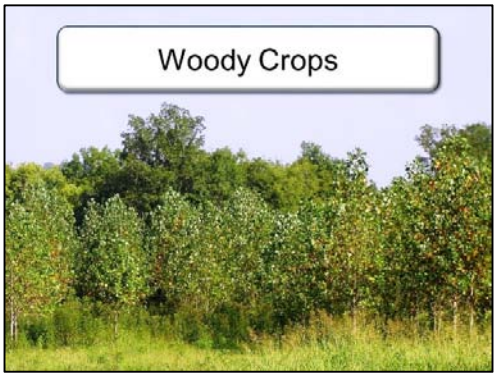
Forage sorghum can also be used to provide livestock feed. It produces an average of 13.7 tons per acre, can grow 6 to 15 feet tall

High-tonnage sorghum can produce 26-43% more than the forage type. The more biomass you produce, the more ethanol you can get out.

Grain sorghum is not as good as corn for livestock but the grain can be processed in traditional ethanol plants and is expected to account for 26% of U.S. grain sorghum use

Slide 18

Woody crops are harvestable year-round, they have a low ash content and consistent energy and sugar content. They are also perennial (i.e. low inputs). Woody crops generally have a net energy ratio of 10-20:1



Slide 18

Woody crops provide ecosystem services (soil conservation, mitigate atmospheric CO2, maintain hydrology)
This material includes residues from logging (59 million dry tons/year) and forest health and hazardous reduction operations (44 million dry tons/yr)

It is estimated that there are 334 million dry tons/year produced in forest wastes and residues

Woody crops grown specifically for bioenergy production include those that are fast growing or short-rotation woody crops like shrub willow (3.5->11 dry tons/acre/yr), hybrid poplar (4-8 dt/acre/yr), loblolly pine (4 dt/acre/yr) and eucalyptus (9-16 dt/acre/yr) (Mercker 2007; Braun et al., 2011).

Slide 19

Biodiesel feedstocks include a number of different types of crops. Some of the more common are canola (rapeseed) (shown on the slide), soybean, sunflower, camelina, castor bean, mustard, safflower.

Slide 19

Most common is soybean due to its additional uses as a protein source for animals and humans and providing N to the soil. About 700 million gallons of biodiesel from soybean was being consumed in the U.S. in 2008. Winter canola and sunflower produce the most oil on a per acre basis (100-130 gallons/acre) and may work well for Tennessee. With biodiesel there is the potential for farmers to produce their own fuel right on the farm since the process is relatively simple and the equipment is available for producing smaller batches.

Test their Knowledge - Questions for the audience

Fossil fuel prices are projected to continue to rise due to increasing consumption rates of __China__ and __developing countries__.

The fossil energy ratio is the ratio of energy __output__ to the fossil energy necessary to __produce__ the fuel.

T or F Fossil energy ratio for gasoline is 0.8 which means it is not very efficient to produce.

The problem with using crop residue is the possibility of removing too much which could result in ___erosion___ or loss of soil __organic matter___, _nutrients__, or ___biota____.

Q: What are the advantages of herbaceous perennials over annual row crops?

1. No annual establishment requirements. (lower economic/energy inputs)
2. Fewer chemical inputs (pesticide/fertilizer).
3. Produce large quantities of biomass.
4. Ecosystem services (soil stabilization, soil carbon sequestration, wildlife habitat)

Q: What are some desirable characteristics of different varieties of sorghum?
A: Can be grown in a number of different climates.
Can increase soil carbon.
Can grow in a range of soils.
Can serve as additional food source for livestock.
High tonnage
Can be processed in traditional ethanol plants

Q: Woody crops that can be used in biofuel production include:
A: Shrub willow, Hybrid poplar, Loblolly pine, Eucalyptus

Q: Examples of biodiesel feedstocks include:
A: Canola, soybean, sunflower, camelina, castor bean, mustard, safflower

Evaluation

Please give us your feedback regarding this activity. Your feedback will help us improve the activities you attend in the future.

Name of Activity: Biofuel feedstocks	Date of Activity:

A. Instruction	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1. The specialist was well prepared.	①	②	③	④	⑤	⑥
2. The specialist presented the subject matter clearly.	①	②	③	④	⑤	⑥

B. General Learning and Change	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1. I have a deeper understanding of the subject matter as a result of this session.	①	②	③	④	⑤	⑥
2. I have situations in which I can use what I have learned in this session.	①	②	③	④	⑤	⑥
3. I will change my practices based on what I learned from this session.	①	②	③	④	⑤	⑥

C. Specific Learning How much ***did you / do you*** know about these subjects?	***Before this program I knew…***					***Now I know….***				
	Very little	Little	Some	Much	Very Much	Very little	Little	Some	Much	Very Much
1. *How biomass energy is produced.*	①	②	③	④	⑤	①	②	③	④	⑤
2. *Types of feedstocks used for biomass energy production*	①	②	③	④	⑤	①	②	③	④	⑤

D. Specific Practices To what degree ***did you / will you*** do the following?	***Before this program I did…***					***In the future I will realistically do….***				
	Very little	Little	Some	Much	Very Much	Very little	Little	Some	Much	Very Much
1. *Grow biomass energy crops*	①	②	③	④	⑤	①	②	③	④	⑤
2. *Seek information related to renewable/biomass energy*	①	②	③	④	⑤	①	②	③	④	⑤
3. *Produce renewable/biomass energy*	①	②	③	④	⑤	①	②	③	④	⑤

E. Satisfaction with Activity	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1. I would recommend this program to others.	①	②	③	④	⑤	⑥

F. Other comments?

Thank you for completing this survey!

TENNESSEE STATE UNIVERSITY
ANR-B13 2015

College of Agriculture, Human and Natural Sciences
Cooperative Extension

Bioenergy

Agricultural feedstocks for cellulosic ethanol and biodiesel

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There are a number of different kinds of crops besides corn that can be used as feedstocks for producing biofuels. Some feedstocks produce readily-available starches or sugars that can be converted to produce ethanol while others produce oil that can be used in biodiesel production (most organic materials can also be burned to produce heat or electricity in the same way that coal is used). Organic materials can also be used to produce cellulosic ethanol which is the same as corn ethanol but requires more processing.

Crop residues

Crop residues, like corn stover (Fig. 1), are the materials left on the field after a crop is harvested and can be used to make cellulosic ethanol. The amount of residue, however, that can be harvested without causing adverse impacts to soil erosion or fertility must be considered. America's first commercial scale cellulosic ethanol plant, in Emmitsburg, IA, uses corn stover to produce 20 million gallons of ethanol per year.

Figure 1. Corn stover baled following corn harvest (F.J. Hay, University of Nebraska-Lincoln)

Perennial Grasses

Perennial grasses are dedicated cellulosic crops that can be used in the same ways as crop residues. Typical species include native warm-season grasses (Fig. 2) such as switchgrass, big bluestem, little bluestem, indiangrass, eastern gamagrass, plus miscanthus.

Figure 2. Switchgrass field in Tennessee.

Benefits of perennial grasses include no annual establishment costs, low chemical input requirements, high biomass production, increased soil organic matter, reduced erosion and improved wildlife habitat. Giant Miscanthus is probably the highest yielding grass for Tennessee's climate but has the highest establishment costs and is not a native plant which could lead to invasive issues.

Sorghum

Sorghum is a summer annual crop with a number of different varieties that can be used for bioenergy production. Sweet sorghum produces readily available sugars that can be fermented to ethanol using the same process as corn ethanol. Forage sorghum (Fig. 3)

Figure 3. Forage sorghum production at Tennessee State University Agricultural Research and Education Center

produces high levels of biomass which can be used to produce cellulosic ethanol.

Grain sorghum produces an animal feed that is of lower quality than corn but can be used to produce ethanol in existing corn ethanol facilities.

Woody crops

Fast-growing woody crops like shrub willow, hybrid poplar (Fig. 4), loblolly pine, and eucalyptus can be regularly harvested and used to produce cellulosic ethanol.

Figure 4. Hybrid poplar production at Tennessee State University Agricultural Research and Education Center

Some of these trees can be harvested year-round (like willow), while others are harvested every 5-7 years (like poplar). They provide benefits to the ecosystem and have consistent energy contents. Forest residues from logging and management practices can also be used to produce cellulosic ethanol and alone produce over 300 million dry tons of production per year (SFAB, 2011).

Oilseed crops

Oilseed crops like soybean, sunflower, and canola (Fig. 5) can be used to produce biodiesel.

Figure 5. Winter canola production at Tennessee State University Agricultural Research and Education Center

The extracted oils can be converted to biodiesel and the meal that is remaining can be used as an animal feed. Sunflower and canola generally contain about 40% oil in the seed while soybean has around 20% oil. Canola can be grown in the winter in Tennessee to help reduce erosion while at the same time producing an additional revenue source for farmers.

References and Resources

SFAB, 2011. Sustainable Feedstocks for Advanced Biofuels
http://www.swcs.org/documents/resources/1_All_Chapters__Sustainable_Feedsto_8A410A56233E6.pdf

eXtension.org - Farm Energy Community of Practice
http://www.extension.org/ag_energy

TSU Extension Publications
http://www.tnstate.edu/extension/publication_index.aspx

Bioenergy: Biomass to Biofuels
http://vermontbioenergy.com/biofuelstextbook/#.Vbwvj_mrSUl

Support for this publication was provided by the USDA National Institute of Food and Agriculture through a Capacity Building Grant.

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