U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ENERGY EDUCATION AND WORKFORCE DEVELOPMENT

Investigating and Using Biomass Gases

Grades: 9-12

Topic: Biomass

Authors: Eric Benson and Melissa Highfill

Owner: National Renewable Energy Laboratory

This educational material is brought to you by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

INVESTIGATING AND USING BIOMASS GASES

AUTHORS

Eric Benson and Melissa Highfill

GRADE LEVEL/SUBJECT

Physical Science
Grade 9
Two to three 50-minute periods

CURRICULUM STANDARD: National Science Education Standards, National Research Council.

Content Standard A:
Students will develop the abilities necessary to do scientific inquiry and understandings about scientific inquiry. Specifically, students will design and conduct a scientific investigation and use appropriate tools and techniques to gather, analyze and interpret data.

Content Standard B:
Students will develop an understanding of changes of properties in matter and transfer of energy. Specifically, students will learn that energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways. Also, in most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion or electricity might all be involved in such transfers.

Content Standard C: For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis.

Content Standard F: Students will develop an understanding of the risks and benefits of technology. Individuals will think critically about the intended and unintended consequences of this technology.

Content Standard G: Students will develop and understanding of the history of science.

Content Standard Z: Have a whale of a good time doing science.

CURRICULUM STANDARD (for the math extension): National Math Standards, National Council of Teachers of Mathematics (NCTM).

Algebra-Represent and analyze mathematical situations using algebraic symbols.

Measurement-Understand measurable attributes of objects and the units, systems and process of measurement.

Data Analysis-Select and use appropriate statistical methods to analyze data.

Connections-Recognize and apply mathematics in context outside of mathematics.

OVERVIEW

In this lesson students will be introduced to biomass gasification and will generate their own biomass gases. Students generate these everyday on their own and find it quite amusing, but this time they'll do it by heating wood pellets or wood splints in a test tube. They will collect the resulting gases and use the gas to roast a marshmallow. Students will also evaluate which biomass fuel is the best according to their own criteria or by examining the volume of gas produced by each type of fuel.

LEARNING OBJECTIVES

- Students will be introduced to biomass as a source of renewable energy.
- Students will discuss the pros and cons of using biomass gasification to produce energy.
- Students will use proper lab techniques to generate and collect biomass gases.
- Students will use the scientific method to create their own scientific investigation.
- Students will analyze their data and draw conclusions.

VOCABULARY

Aerobic
Aerosol
Anaerobic
Biomass
Combustion
Erlenmeyer Flask
Gasification
Pyrolysis
Renewable Energy
Syngas

MATERIALS

SYNGAS SYNTHESIS AND USE MATERIALS (per group)

-Safety Glasses
-Lab Coats
-Latex or nitrile gloves
-35-55 mL test tube with matching one-hole rubber stopper
-2 Ring stands with metal test tube clamp and clamp for Erlenmeyer flask
-3 pieces stainless steel or glass tubing, each approx. 5 cm long
-250 mL Erlenmeyer flask with matching 2-hole stopper
-3 pieces rubber or Tygon tubing, 2 approx. 60 cm long and 1 just shorter than the Erlenmeyer flask
-Bunsen burner
-Sink with faucet connection for tubing
-Wood pellets or wood splints (enough to fill test tube approx. 3/4 full)
-Regular-sized Marshmallows (not the minis)

-Skewers for roasting the marshmallows
-1 large Ziploc bag for test tube disposal

STUDENT INVESTIGATION MATERIALS (per group)

Students will generate a list of their own materials but should have access to at least the following items:

-All supplies from the Syngas Synthesis and Use section
-A variety of types of biomass such as:
  -crushed wood pellets or wood splints
  -dried grass
  -nut shells
  -manure
  -corn stover
-200 mL graduated cylinder
-Balance

PREREQUISITE KNOWLEDGE

-Students should already understand and have used the scientific method in setting up prior experiments. This should include basic lab techniques such as lab safety, measuring and data collection.
-Students should be introduced to the experiment, and the difference between combustion and pyrolysis should be discussed.

ADVANCED TEACHER PREPARATION

1. Cut three pieces of glass or stainless steel tubing to approximately five cm for each group of students.
2. Carefully push the tubing through the three holes in the stoppers (see Figure 1).

PROCEDURE FOR SYNGAS SYNTHESIS AND USE (DAY 1)
Although the gases produced are trapped in the flask, it is advisable to synthesize the syngas in a fume hood if possible.

1. Fill test tube 3/4 full with wood pellets or wood splints. If using wood splints, break them into pieces to make sure enough splints will fit into the tube.
2. Clamp the test tube to the ring stand using the metal clamp and adjust the height of the tube relative to the Bunsen burner.
3. Insert the one-hole stopper with tubing into the test tube.
4. Attach the rubber tubing to the bottom of the two-hole stopper on one side.
5. Fill the Erlenmeyer flask full of water and insert the two-hole stopper with the tubing going into the water. The tube should almost touch the bottom of the flask.

6. Connect the test tube and the Erlenmeyer flask with the piece of rubber tubing from step three.
7. Connect the last piece of rubber tubing to the two-hole stopper and place the other end into the sink. See Figure 1 to ensure correct set-up.

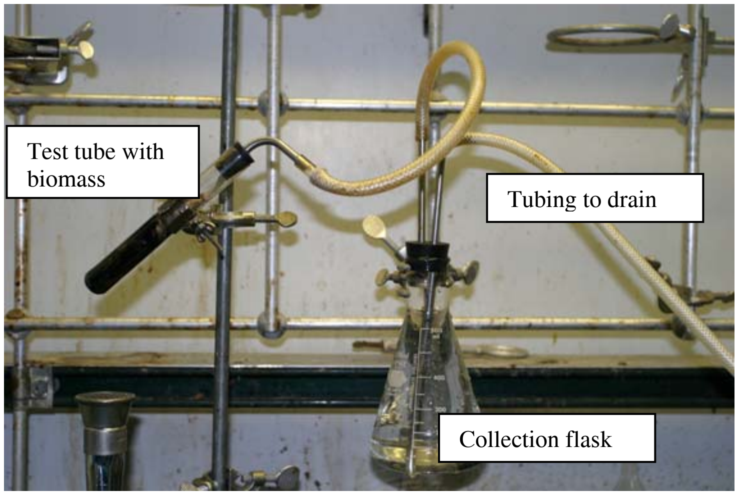

Figure 1. Equipment Set-up for Gas Collection.

8. Light Bunsen burner and begin heating the test tube. Make sure the flame is at least three cm away from the test tube so that the tube does not melt.
9. Record observations while the tube is being heated.*
10. After a few minutes gas will be evolved and will begin to displace the water in the Erlenmeyer flask. Continue heating until all of the water has been displaced.
11. At this point have the teacher disconnect the hot test tube tubing from the Erlenmeyer flask and move the hot test tube out of the way of the experiment. Wear leather gloves.
12. Connect the drain tubing to the faucet.
13. Slowly turn on the water and light the gas flowing from the end of the glass tubing. Adjust water flow rate to maintain a constant flame.
14. Roast a marshmallow (but don't eat it-it might have a little tar on it-yucky!).
15. Return to the classroom and have a fresh yummy marshmallow.

CLEAN-UP

1. Once the test tubes are cool to the touch (this may be after the class period is over, so the teacher may do this step), remove them from the clamp and place the tubes and their contents in the Ziploc bag. The tubes are very stinky! Once the bag is sealed it can be disposed of in the trash.
2. Wash the dirty tubing and flask in hot soapy water to remove any oils. If oils remain, rinse with acetone.

PROCEDURE FOR STUDENT INVESTIGATION (DAY 2)

Depending on the students and the amount of time, the teacher could assign student groups the task of determining which type of biomass is the "best." Students would set their own parameters for what the "best" means, but would need to support their conclusions with experimental data. This data would come from experiments of their own design.

If the teaching method above doesn't fit the students or the time constraints, a guided inquiry approach could be used. In this approach, what is meant by the "best" biomass is discussed as a class. One possible measure of the "best" biomass source could be the volume of gas produced by one gram of material. Using the collection procedure above, student groups could measure the volume produced by one or more sources of biomass. Class data could then be compared and discussed.

POST-LAB CLASS DISCUSSION

1. *Discuss lab observations, results and conclusions. One likely observation will be the presence of smoke in the flask. This might be a good time to discuss the difference between aerosols and gases.
2. Ask students what the gas consists of, and explain that the gas is a mixture of methane, hydrogen, carbon monoxide, carbon dioxide. The methane, carbon dioxide and hydrogen are the components of the gas that actually burn.
3. Why did we roast the marshmallow?
4. Discuss real-life gasifiers and biomass gasification research. For more information on gasification see http://www.nrel.gov/biomass/, and the following teacher information sheet. Compare the experiment with actual gasification (this experiment is at a much lower temperature than commercial gasification and produces more pyrolysis oils than gas).
5. Discuss the environmental impacts of biomass gasification, both positive and negative.
6. What is the "best" source of biomass according to the student's tests? Results may vary, but equal amounts of biomass produce similar volumes of gas. In general, the best source of biomass is what is available in the area. Transporting biomass is expensive!

EVALUATION

-Use a lab rubric to evaluate the experiment. Students could be assessed on participation, safe lab technique and data collection.
-A written lab report could be evaluated by the teacher or by student groups.
-Have students complete the Biomass Gasification worksheet for homework. This could be used to facilitate the post-lab discussion.
-A short essay could be written summarizing what students learned from the lab. This should include relevant terminology, a summary of gas collection procedures and the implications of large-scale gasification as a source of renewable energy.

MATH EXTENSION (One class period)

-Have students bring in energy bills from home to use for this activity.
-Have students complete the Biomass Home Energy Analysis worksheet.

BIOMASS GASIFICATION WORKSHEET

1. What was the best source of biomass according to the data?

Answers to this question will vary depending on the types of biomass used and the amount of experimental error the students had in performing the gas collection. There is no single correct answer.

2. What was the worst source?

Answers to this question will also vary depending on the types of biomass used and the amount of experimental error the students had in performing the gas collection. There is no single correct answer.

3. What is the percent difference between the amount of gas produced by the best source and the worst source?

The percent difference should be small, hopefully on the order of 5 to 10%. If the percent differences are calculated to be larger than this, it is most likely due to variances in the experimental procedure.

4. What are some other things to consider if you are choosing a source of biomass to produce electricity?

The cost of transporting the biomass to the gasifier can make gasification prohibitively expensive. The best source of biomass is generally whatever is found in the area. As a rule, biomass is not shipped more than fifty miles for use in gasification.

5. What are the benefits of biomass gasification compared to other energy sources (solar, wind, coal, etc.)?

Biomass gasification can be used in places where the conditions for solar and/or wind power are not ideal. Biomass gasification is a much cleaner process than using coal to produce electricity, and it does not rely on any fossil fuels. The syngas produced can also be used to produce many energy-rich products such as hydrogen gas and cleaner-burning diesel fuel.

6. What are the drawbacks of biomass gasification compared to other energy sources?

There are other products formed during biomass gasification, including organic tars that must be disposed of as hazardous waste. Students may have noticed evidence of these tars in their test tube in the form of aerosols or oils. Also, if large amounts of biomass are not supplied close by, the process can become very expensive.

BIOMASS HOME ENERGY ANALYSIS

1. Use the four energy bills you brought from home to fill in table 1.

Table 1: Home Electricity Use

Month	Electricity Used (KW)

2. Calculate the average monthly kilowatt usage for the four months.

Average monthly electricity use = _______________ KW

3. Use the four energy bills you brought from home to fill in table 2.

Table 2: Home Gas Use

Month	Therms Used

4. Calculate the average monthly therm usage for the four months.

Average number of therms used per month = _______________

One therm = 100,000 BTU's. A BTU is a British Thermal Unit. One BTU is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit.

For the rest of your calculations, use the averages from #2 and from #4.

5. What was the average number of BTU's used in your home? _____________ BTU's

In general, one kilogram of dry biomass can produce about one kilowatt (KW) of electricity.

6. How many kilograms of biomass would be needed to meet your home's average electricity needs?

________________ kg

7. Look at class data.
   a. Which type of biomass produced the greatest volume of gas per gram?

   ____

   b. How many liters of gas were produced by one gram of this biomass?

   __________L

   c. Which type of biomass produced the least volume of gas per gram?

   ____

   d. How many liters of gas were produced by one gram of this biomass?

   __________L

The energy content of syngas is relatively consistent regardless of the biomass used or the gasification methods. For the following questions use the conversion below:

1 L of syngas contains 13.4 BTU's of energy.

8. How many liters of gas would be needed to produce the average number of therms used by your household ?

__________________L

9. How many kilograms would be required to produce the number of liters you calculated in number eight if…

   a. The biomass type from 7a were used for gasification?

   b. The biomass type from 7c were used for gasification.

10. If the biomass from 7a were used as the energy source, how many kilograms of it would be needed to meet both your home's electric and gas needs for one year?

11. If the biomass from 7c were used as the energy source, how many kilograms of it would be needed to meet both your home's electric and gas needs for one year?

12. A semi-truck can haul about 40,000 pounds per load. (1 kg = 2.2 pounds) How many loads would be necessary to haul the amount of biomass you calculated in number 10?

13. How many loads would be necessary to haul the amount of biomass you calculated in number 11?

14. The cost of biomass is approximately $30 a dry ton. (1 ton = 2,000 pounds) What would be the cost of the biomass necessary to provide your home's energy requirements for a year if…

a. You used the biomass from 7a?

b. You used the biomass from 7c?

15. Not only does the biomass itself cost money, it also costs to transport it to your home. The price of using a semi-truck is approximately $2.75 per mile per load. What would be the total transportation cost of hauling one year's worth of the biomass from 7a to your home if the source of this biomass were

a. 10 miles from your house?

b. 100 miles from your house?

c. 500 miles from your house?

16. What would be the total transportation cost of hauling one year's worth of the biomass from <u>7c</u> to your home if the source of this biomass were

a. 10 miles from your house?

b. 100 miles from your house?

c. 500 miles from your house?

17. The total cost of the biomass is the cost of the biomass itself plus the cost to transport it. Complete the "Total Cost" data table (table 3) below.

Table 3: Total Biomass Cost

	Total cost if shipped from		
Biomass	10 miles	100 miles	500 miles
(7a)			
(7c)			

18. It has been said that the best biomass is what's available. Explain this statement with the help of the numbers you calculated for table 3.

19. Use your four energy bills to determine the average price your family pays for home energy each month. Use this average monthly energy bill to determine the energy cost for your home for one year.

20. How does the cost of energy you calculated in number 19 compare to what it would cost to use biomass as your home's energy source?

21. For urban areas it doesn't make economic sense to use small, individual gasifiers to meet home energy needs. But it might make sense for power companies to provide more energy from biomass. Support this statement.

22. When might it be a good idea to install a small, modular gasifier?

Bonus (algebra connection):

A source of the biomass from 7c is 50 miles from your house. A source of the biomass from 7a is further away. How close would this biomass source need to be so that the price of providing biomass energy for your home for one year would be the same for either source?

BIOMASS HOME ENERGY ANALYSIS

Example calculations and answers (student answers will vary):

1. Use the four energy bills you brought from home to fill in table 1.

Table 1: Home Electricity Use

Month	Electricity Used (KW)
January	850
April	710
July	800
October	727

2. Calculate the average monthly kilowatt usage for the four months.

Average monthly electricity use = _____772__________ KW

3. Use the four energy bills you brought from home to fill in table 2.

Table 2: Home Gas Use

Month	Therms Used
January	141
April	88
July	22
October	92

4. Calculate the average monthly therm usage for the four months.

Average number of therms used per month = ___86____________

One therm = 100,000 BTU's. A BTU is a British Thermal Unit. One BTU is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit.

For the rest of your calculations, use the averages from #2 and from #4.

5. What was the average number of BTU's used in your home? ___8,600,000___ BTU's

In general, one kilogram of dry biomass can produce about one kilowatt (KW) of electricity.

6. How many kilograms of biomass would be needed to meet your home's average electricity needs for one month?

________772________ kg

7. Look at class data.

   a. Which type of biomass produced the greatest volume of gas per gram?

   _____various answers__________________

   b. How many liters of gas were produced by one gram of this biomass?

   _____.150______L

   c. Which type of biomass produced the least volume of gas per gram?

   _________various answers______________

   d. How many liters of gas were produced by one gram of this biomass?

   ______.135_____L

The energy content of syngas is relatively consistent regardless of the biomass used or the gasification methods. For the following questions use the conversion below:

1 L of syngas contains 13.4 BTU's of energy.

8. How many liters of gas would be needed to produce the average number of therms used by your household ?

8,600,000 BTU ÷ 13.4 BTU/L = 641791 L

9. How many kilograms would be required to produce the number of liters you calculated in number eight if…

   a. The biomass type from 7a were used for gasification?

   641791 L ÷ .150 L/g = 4,278,607 g ≈ 4,279 kg

   b. The biomass type from 7c were used for gasification.

   641791 L ÷ .135 L/g = 4,754,008 g ≈ 4,754 kg

10. If the biomass from 7a were used as the energy source, how many kilograms of it would be needed to meet both your home's electric and gas needs for one year?

772 kg + 4,279 kg = 5,051 kg

5,051 kg/month • 12 months/year = 60,612 kg/yr

11. If the biomass from 7c were used as the energy source, how many kilograms of it would be needed to meet both your home's electric and gas needs for one year?

772 kg + 4,754 kg = 5,526 kg

5,526 kg/month • 12 months/year = 66,312 kg/yr

12. The cost of biomass is approximately $30 a dry ton (one ton = 2,000 lb.) What would be the cost of the biomass necessary to provide your home's energy requirements for a year if…

a. You used the biomass from 7a?

60,612 kg • 2.2 lb./kg ≈ 133,346 lb.
133,346 lb. ÷ 2,000 lb./ton = 66.67 tons
66.67 tons • $30/ton ≈ $2,000

b. You used the biomass from 7c?

66,312 kg • 2.2 lb./kg ≈ 145,886 lb.
145,886 lb. ÷ 2,000 lb./ton = 72.94 tons
72.94 tons • $30/ton ≈ $2,188

13. A semi-truck can haul about 40,000 pounds per load. How many loads would be necessary to haul the amount of biomass you calculated in number 10?*
(1 kg = 2.2 lb.)

40,000 lb ÷ 2.2 lb/kg ≈ 18,182 kg

60,612 kg ÷ 18,182 kg/load ≈ 3.33 loads
Therefore, four loads would be needed.

The maximum weight the truck can haul is not the only factor limiting load size. The trailer of the truck has a limited volume. Unless biomass is compacted (which is an additional expense), its volume likely determines how much of it can be hauled. An extension activity would be to determine the density of each of the two types of biomass. From this students could calculate how much would fit into a truck trailer, and how many loads would be required. Trailers are about 40 ft. X 8 ft. X 8 ft.

14. How many loads would be necessary to haul the amount of biomass you calculated in number 11?

66,312 kg ÷ 18,182 kg/load ≈ 3.65 loads
Therefore, four loads would be needed.

15. The cost of transporting cargo using a semi-truck is approximately $2.75 per mile per load. What would be the total transportation cost of hauling one year's worth of the biomass from 7a to your home if the source of this biomass were

a. 10 miles from your house?

4 loads • 10 miles/load • $2.75/mile = $110

b. 100 miles from your house?

4 loads • 100 miles/load • $2.75/mile = $1,100

c. 500 miles from your house?

4 loads • 500 miles/load • $2.75/mile = $5,500

16. What would be the total transportation cost of hauling one year's worth of the biomass from 7c to your home if the source of this biomass were

a. 10 miles from your house?

Since it will also require four loads of this biomass, the calculations are the same as in #15.

$110

b. 100 miles from your house?

$1,100

c. 500 miles from your house?

$5,500

17. The total cost of the biomass is the cost of the biomass itself plus the cost to transport it. Complete the "Total Cost" data table (table 3) below.

Table 3: Total Biomass Cost

	Total cost if shipped from		
Biomass	10 miles	100 miles	500 miles
(7a)	\$2000 + \$110 = \$2110	\$2000 + \$1100 = \$3100	\$2000 + \$5500 = \$7500
(7c)	\$2188 + \$110 = \$2298	\$2188 + \$1100 = \$3288	\$2188 + \$5500 = \$7688

18. It has been said that the best biomass is what's available. Explain this statement with the help of the numbers you calculated for table 3.

Transportation costs greatly outweigh any energy differences between biomasses. For example, if there was a source of lower energy biomass (such as 7c) within 10 miles of a home, it would cost \$2,298 to supply the home with energy for the year. Whereas it would cost \$3,100 to supply the same amount of energy to the home using a higher energy source that had to be transported 100 miles.

The differences in energy produced by various biomass sources are very small. The cost of transporting biomass is relatively large.

19. Use your four energy bills to determine the average price your family pays for home energy each month. Use this average monthly energy bill to determine the energy cost for your home for one year.

Month	Monthly Energy Bill
January	\$179
April	\$128
July	\$110
October	\$144

Average monthly energy bill = \$115.50

Yearly energy cost = \$115.50 • 12 = \$1,386

20. How does the cost of energy you calculated in number 19 compare to what it would cost to use biomass as your home's energy source?

Home energy costs from biomass are much greater than from traditional energy sources, even if the source of the biomass is within ten miles of where it is used. And this doesn't even take into account the price of an individual, modular gasifier.

21. For urban areas it doesn't make economic sense to use small, individual gasifiers to meet home energy needs. But it might make sense for power companies to provide more energy from biomass. Support this statement.

* Larger users of biomass, such as power companies, will be able to ship larger quantities and will have greater transportation options (such as rail). This will reduce the cost of biomass transportation.

* Power companies will operate larger gasifiers that may be more efficient than individual, modular gasifiers.

* Power companies will be able to generate a greater percentage of energy from a renewable resource, rather than from a nonrenewable such as coal.

* The net change of CO_2 in the atmosphere will be zero or close to zero. This is because the biomass source will have used about the same amount of CO_2 while growing as is released through gasification and later combustion of the gases.

22. When might it be a good idea to install a small, modular gasifier?

*Environmentally conscious home owners who can afford the cost of the gasifier as well as the increased energy costs may want to install a modular unit.

* Remote areas that don't have easy access to the power grid may consider using modular gasifiers. The unit and cost of biomass may be cheaper than hooking up to the grid.

* Many countries do not have a power grid. Modular gasifiers or other energy sources (i.e wind turbines, photovoltaic panels) may be the only options for power.

Bonus (algebra connection):

A source of the biomass from 7c is 50 miles from your house. A source of the biomass from 7a is further away. How close would this biomass source need to be so that the price of providing biomass energy for your home for one year would be the same for either source?

Let x = number of miles the biomass is transported

$2,188 + 4(50)($2.75) = $2,000 + 4x($2.75)

x ≈ 67.1

Therefore, the greater energy producing biomass would have to be less than 67.1 miles away. At any distance more than that, the lower energy biomass would be the better choice.

Actually, no matter what the distance for biomass 7c, the greater energy biomass from 7a would have to be within 17.1 miles of the source for biomass 7c for 7a to be a better value. This problem emphasizes again the fact that the best biomass is what is in the area.

TEACHER BACKGROUND INFORMATION

What is biomass?

Biomass is plant matter or other biological material of non-fossil origin such as wood chips, corn stover, and manure.

What are some of the uses of biomass?

Energy:

Combustion (burning in the presence of oxygen) of biomass has been an energy source since humans (or prehumans) first discovered fire. Biomass fires are, of course, still used for heating, cooking and roasting marshmallows. The heat from combusting biomass can also be used to create steam to drive a turbine and generate electricity.

Biomass can also be heated under no oxygen (anaerobic) or low oxygen conditions. If the temperature is between 400^0C and 700^0C, this process is called pyrolysis. The oils produced from pyrolysis (pyrolysis oils) can either be burned for use as an energy source or turned into bioproducts (see below).

If the biomass is heated at temperatures above 700^0C (still under anaerobic or low oxygen conditions), the products formed are mainly the result of gasification. Gasification produces gases called syngas. The main components of syngas are hydrogen, methane, carbon monoxide, and carbon dioxide.

Syngas (or some combination of its component gases that excludes carbon dioxide) can be burned directly to power a turbine and generate electricity. The hot gases that come out of the turbine can then be used to create steam to power a second turbine. This process is known as the integrated gasification combined cycle (IGCC). The IGCC is very difficult using simple combustion of biomass. This is one advantage of gasification over combustion.

Another way to produce electricity from syngas is to run it directly into an engine that powers a generator. The syngas doesn't need to be as clean (pure) to run an engine as it does to run a turbine. The syngas would also have to be very clean (pure) to use it to make biofuels. Biofuels are a more valuable commodity than electricity and include biodiesel. If gasification produces hydrogen that is more than 99.99% pure, it could be used in fuel cells.

See http://www.nrel.gov/learning/re_biomass.html or http://www.gocpc.com for more information and links to other biomass energy (bioenergy) sites.

Bioproducts:

Pyrolysis oils and the hydrogen, carbon monoxide and methane produced from gasification can be used to synthesize a variety of products usually made from the byproducts of petroleum refining. These products are called bioproducts and include plastics, fertilizer, methanol, antifreeze and other chemicals. See http://www.nrel.gov/learning/re_bioproducts.html for more information and links to other biomass and bioproduct sites.

Why gasify?

1) Reduce US dependence on foreign oil.
2) The amount of CO_2 produced during biomass gasification and from the burning of the resulting syngas is close to the amount of CO_2 used by the plants that formed the biomass. This means there is no net CO_2 added to the atmosphere as there is when petroleum products or coal are burned.
3) Support farmers and other biomass producers (i.e. sawdust from lumber industry). Biomass that formerly was waste now has value.

Why isn't gasification more widely used?

Generally, gasification is still a more expensive way to produce energy and products than is using oil or coal. A major contributor to this higher cost is the removal of the waste products (tars and ash) produced during gasification. Much of the current research on gasification is focused on ways of reducing, eliminating or using the waste tars.

What is the best biomass?

One attraction of gasification is that it can use virtually any source of biomass. And no matter what the source is, the amount and composition of the syngas produced per dry ton of biomass is almost the same. Also, even though the amount and composition of the waste products can vary somewhat between biomass sources, disposal costs are small compared to the cost of collecting and transporting the biomass. Therefore, the best biomass is what is available in the area. For example, a biorefinery in Vermont would minimize its costs by using woodchips or sawdust while one in Iowa would do better using corn stover.