

**Overview:** This module is designed to provide students with hands-on experience with biomass gasification using the “woodgas camp stove”.

By the completion of this module, students will be able to:

1. Build a simple gasifier (woodgas camp stove)
2. Demonstrate the safe use of hand tools
3. Describe the basic process of wood gasification
4. Explain one or more ways that wood gasification is more efficient than “traditional” combustion of wood

**Concepts/processes:** gasification/pyrolysis, ventilation (air/oxygen) and combustion, energy density, efficiency (relate to smoke)

**Module duration:** 2-3 hours with both the PowerPoint presentations and a camp stove activity (can be broken into multiple class periods if necessary)

**PowerPoint presentations:** annotated slides are provided.

**Wood gas camp stoves:**

**Materials and supplies** required for each student (pair of students; most tools can be shared between 1-2 pairs/groups):

1. 12-oz aluminum soda/beverage can
2. 14.5 to 16-oz “tin” can (e.g., a soup can, large enough to nest a soda can in; other sizes will work and can be experimented with)
3. 4” Scratch awl (or comparable tool—can be fabricated from 1” dowel and a deck screw—screw into dowel, then cut head and sharpen)
4. 7/16" x 5" Center Punch (or comparable tool—can be fabricated by sharpening the end of a metal bolt)
5. Hammer
6. 3/16" dowel (cut to ~6" length, sharpened with a pencil sharpener)
7. Swing-a-way hand-operated can opener (can be shared between 1-2 groups/pairs)
8. 12” Ruler (optional)
9. Sharpie marker (dark color)
10. Fuel: wood pellets, nut shells, dry branches (broken into small pieces), charcoal, coal, etc.
11. Fire starter gel (enough to coat 6-8 wood pellets (or other biomass fuel))
12. Bottle (e.g., prescription bottle) to mix gel and fuel in (optional)
13. Lighter (instructors will probably want to wield the lighter...)
14. Gloves and safety glasses (for working with metal and hot stoves/pans)
15. Data sheet for recording information (1 per group)
16. Options for “something to cook” or heat up: pot/can of water (tea or cocoa, soup), marshmallows (with toothpicks to cook with), etc.
17. Gallon metal can with a piece of welded wire mesh (suggested, to shelter the stoves and provide something to place a cooking pot on)

*Instructions:* Although the Woodgas Camp Stoves “visual instruction guide” is fairly self-explanatory, the following instructions can be used in conjunction with the included visual guide. Be sure to read the caution statement and other notes at the bottom of the visual instruction guide.

1. Assemble the necessary materials and tools as outlined above.
2. Start by turning the aluminum soda can upside down. Mark vent hole locations using a permanent marker. A total of 12 to 15 vent holes generally works quite well. Be sure to be careful using the awl (they are sharp!). Use a hammer to tap the awl.
3. Using a permanent marker and a ruler mark a reference line approximately 1 inch from the top of the aluminum can for the burner air inlet ports. Different arrangements (number and spacing) of inlet ports can be used. 10 air inlet ports seem to work quite well. The red and blue scale printed along the edge of the first page of the “visual instruction guide” can be used for a 10 port arrangement.
4. Using the awl, carefully punch the air inlet holes. This is best done by hand (without the use of a hammer, since the sides of the aluminum can will tear easily). You can expand the air inlet holes using a sharpened wood pencil or a dowel. A diameter of 3/16” (0.5 cm) works quite well.
5. The final step with the aluminum can is the removal of the top. After all your hard work punching holes, be sure to take your time using the can opener to remove the top. Once you've removed the top, set the aluminum can aside.
6. Now take the “tin” can and remove any paper label (if still attached). Then mark out five vent hole locations. One should be in the bottom (center) of the can. The other four holes can be placed around the perimeter of the base of the can. Using a hammer and a center punch, carefully make the vent holes.
7. Next, assemble the stove: nest the aluminum soda can snugly inside the soup can. The aluminum soda can should rest on the bottom of the tin can. If necessary, use the awl to bend the sharp edges of your air vent holes in the tin can so they do not puncture the aluminum can or prevent the aluminum can from being properly seated on the bottom of the tin can.
8. Select a fuel source, preferably a renewable biomass fuel! Measure out the quantity (mass or volume) that you plan to use. The stove’s maximum capacity is about ½ inch below the burner air inlet ports.
9. Load the fuel into the aluminum can.
10. Select a smokeless, non-explosive starter gel (or lamp oil).
11. Coat or soak 6 to 8 pellets in the starter gel/oil and then load them on the top of the fuel in the aluminum soda can.
12. Before igniting the fuel in the soda can, be sure you are in a well ventilated area, preferably outdoors (or a chemistry lab with a ventilated hood), far enough away from flammable or explosive materials (general fire safety rules apply). If doing this experiment/demonstration outdoors, it is useful to place the camp stove inside a gallon can (see step#14 photo). A layer of small gravel can be placed in the bottom of the gallon can to ensure ventilation at the bottom of the camp stove. The fuel in the wood gas camp stove should be ignited from the top of the fuel in the aluminum soda can.

13. After a couple of minutes, the wood gas camp stove should begin to produce gas, and flames should appear at the burner air inlet ports. As the gas production proceeds, the color and quality of the flame will change.
14. If you used a gallon can to shelter your camp stove, a section of welded wire mesh can be placed over the top of it to hold a small pot, and you can boil some water for a hot beverage or soup!
15. Eventually the camp stove will stop producing gas, and it will shift over to a charcoal burn.
16. The charcoal burning provides excellent heat for toasting marshmallows!

*Other experiments:* There are many options available for expanding the wood gas camp stove demonstration. Here are some suggested experiments (and questions) that can be conducted using the wood gas camp stove (in increasing complexity):

“Experiment” 1 (Demonstration, as outlined above): Build and run the stove on wood pellets. It is a dramatic and fascinating demonstration for most people, especially kids: the solid fuel at the bottom of the can is separated from the combustion of the woodgas at the top of the can.

Experiment 2: Compare traditional combustion (e.g., a “campfire”: small quantity of sticks in a ventilated gallon can, light from the bottom, etc.) to gasification. Suggested questions: Hypothesize which will burn longer using the same mass of wood? Why? Which will produce the most smoke? Why? What is smoke made up of? Which do you think is most efficient at converting an equal mass of wood to usable heat? Why? How could you test that (scientifically)? [Possible approach: The time it takes to boil an equal volume of water (in identical containers), and the length of time that the boiling is sustained—is a pretty well established approach, but they may think of other approaches that would work.]

Experiment 3: Try several ventilation and/or burner designs (e.g., modify air inlet: size, shape, number, locations/height). Example questions: What designs did you try (sketch, describe)? Why did you select those designs? How did they work in comparison to the “standard” 10-inlet burner design? What criteria did you use for comparison (e.g., length of gas burn, time needed to boil water, duration of water boiling, color or type of flame output, robustness to breezes—does one design work better in windy conditions?) and what were the outcomes?

Experiment 4: Built two identical stoves; select two different fuels: describe the fuels in terms of their physical density, shape, size, moisture content, etc.; hypothesize what their relative **energy densities** are (e.g., which will burn longer/boil water longer if you use the same volume of the two fuels; alternatively, the same mass of the fuels). There are countless fuel combinations that could be evaluated: wood pellets vs. nut shells, wood pellets vs. charcoal briquette, wood pellets vs. anthracite (coal), rabbit droppings vs. commercial wood pellets, rabbit droppings vs. pelletized rabbit feed! [Suggest/require that a standard/fair method for comparing the energy output be used—e.g., the boiling water approach from the previous experiments].