






Where Wood Works

Strategies for Heating with Woody Biomass

Welcome

National Leadership

"We are on the brink of a new healthy forest economy that will sustain large-scale forest restoration in the long run. The rapid growth of a young bioenergy industry holds the promise of a reliable and expanding market to use the small trees supplied by forest restoration projects for cleaner and cheaper energy sources."

Rick Cables
Rocky Mountain Regional Forester
Forest Service, USDA

"Technology is taking wood use to new levels. BLM is committed to providing biomass to help meet future needs for energy and value-added products, while reducing the risk of catastrophic wildfire."

Gregg Nelson
National Biomass Coordinator
Bureau of Land Management

"Matching the bioenergy technology to the available forest resource is extremely important. Sometimes, smaller scale applications such as heating a community building makes the most sense."

Marcia Patton-Mallory, PhD
Biomass and Bioenergy Coordinator
Office of the Chief
Forest Service, USDA

Colorado Leadership

"Renewable energy resources such as biomass are key components of the New Energy Economy. Through effective use of biomass resources we can reduce our dependence on fossil fuels, improve forest health, protect our environment and stimulate local economies."

Tom Plant
Director,
Colorado Governor's Energy Office

"Wood is the environmentally friendly fuel source of the future because it is carbon neutral and renewable. When we begin actively including wood in the energy equation we also contribute to improved forest health, safer watersheds, and reduced fire risks."

Jeff Jahnke
Colorado State Forester

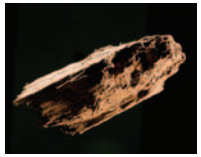
"To create a truly environmental and sustainable energy source we must look to biomass utilization as our answer for the future."

Jeff Kitchens
Colorado Forest Program
BLM

Wood Can Work for Your Community

If your community is looking for ways to reduce heating bills and you are near a forest, you have probably considered using wood for heat. Yes, it can work! It can reduce your heating bills, address regional forest health issues, and help keep more of your energy dollar in your community. But it could also be a disaster. The wrong technology for the wrong application with wrong expectations is a recipe for getting burnt on wood. This article shines light on the pitfalls and potential of wood-fuel applications.

The Basic Technologies



CHIP SYSTEMS are well-suited for large buildings and campuses. Successful projects get their chips locally, usually within 30 miles or so. Chip-handling systems are complex and expensive to build and operate. This is offset by the low cost of the fuel itself.

PELLET SYSTEMS work very well at the residential scale and are beginning to be used in commercial buildings. In Europe, pellets are delivered in bulk to heat entire towns and they are even used as a zero-carbon substitute for coal in large electric power plants.

CORDWOOD SYSTEMS heat large mountain homes, winter lodges and camps, and even swimming pools. In the right location, the fuel (basically firewood) is free or nearly so. These systems must be manually loaded once or twice a day with up to 100 pounds of wood. Great exercise!

COMBINED HEAT AND POWER (CHP or cogeneration)—the production of heat and electricity from wood—is very promising. Today, it works very well in large lumber mills, paper mills, and furniture factories. In the future, it may even work for smaller applications.

EMERGING TECHNOLOGIES are being developed by governments and industries looking for low-carbon, low-cost energy sources. Wood can be ***gasified.*** The gas can be used to fire a boiler, drive an engine or turbine, and even run a fuel cell. Wood can be ***liquefied*** into liquid biofuels for transportation. These technologies are being prototyped today and should be commercially viable within the next decade.

THE BOTTOM LINE

Is your building...

More than 100,000 square feet?

If you have more than 100,000 square feet to heat in a moderately cold climate and you're located near a stable supply of wood chips, you may have a winner. If the building is a hospital, prison, or dormitory, even smaller buildings might make sense since these buildings use lots of hot water year round.

Less than 10,000 square feet?

If you have a building less than 10,000 square feet to heat and you live in a moderately cold climate, a wood pellet solution might work for you even if you're far from the nearest tree. And if you don't have access to natural gas, things look even better.

The Messy Middle!

Buildings in the 10,000–100,000 square feet range are the most likely building you'll be planning and, unfortunately the least likely for a simple off-the-shelf wood-fueled solution. But, please read on. There are some very exciting systems heading your way—and you really should consider designing your building to take advantage of them when they arrive. Flexible Energy Communities Initiative can help!

A Few Things to Think About

Some Key Opportunities and Issues...

AIR QUALITY should always be a concern. Wood-fueled systems can be made to meet any air quality standard, but there are cost trade-offs. The good news is that burning wood in a properly designed and maintained system is ***much*** cleaner than burning it in a slash pile or wildfire. In some situations, a wood-fueled system can actually improve local air quality.

WILDFIRE MITIGATION

ALTERNATIVE TO SLASH PILE BURNS

ALTERNATIVE TO PRESCRIBED BURNS

Fuel-reduction and restoration activities are key components of forest management policies.

- *Land treatment projects are expensive and funds are not always available.*
- *Slash burning and prescribed burns can adversely impact local air quality.*
- *In situations where outdoor burning is prohibited, local landfills are often the only alternative.*

Developing local wood-fuel markets can help offset treatment and disposal costs. This also creates local jobs, which keeps more money in your community.

SUPPLY QUALITY. If you use wood pellets, the quality is very high and very uniform. However, wood-chip quality varies a great deal, depending on how the material is handled. "Treat it like fuel and it is fuel; treat it like trash and it is trash." Training, awareness, and long-term business relationships are the keys to success for a dependable, quality wood chip supply.

SUPPLY AVAILABILITY. For wood-fuel systems to work, you will need a reliable, long-term supply. The weight and bulk of wood-fuel will keep your supply geographically nearby. A forest might burn, or environmental regulations may reduce access to some areas, forcing you to travel further for your wood supply. This could incur significant transportation costs—making wood the high-priced fuel.

CARBON-NEUTRAL. Wood-fuel is considered carbon-neutral. While carbon dioxide is emitted when wood is burned, the very same amount of carbon dioxide is absorbed when the tree grows. When wood-fuel is used to offset fossil fuels such as propane and natural gas, the net effect is lower carbon emissions, allowing carbon credits to be sold.

Wood is Working for Other Communities

Wood as fuel is making a comeback around the country as the cost of other energy sources continues to rise. In many areas, forest management activities produce potential fuel. Clean wood technology is becoming available and affordable—and the word is getting out. Wood works, and your community can learn from communities where it does!

Successful Projects Almost Always Have...

1

A Good Local Wood Source. You won't find many wood-fueled systems too far from a forest. Wood is bulky and often full of moisture, two things that make transporting this fuel long distances impractical. However, wood pellets are routinely shipped from Canada to higher-priced markets in Europe.

2

The Right Team—The Right Technology. To make wood-fueled systems work for your community, you need to choose the right technology that matches your building's needs. The best way is to take advantage of the experience of others, especially at the early design stages. Fortunately there are people to help!

3

Political Will and Long-Term Commitment. The economics and logistics of wood-fuel systems can work, but it is seldom a slam-dunk. Wood systems typically cost two to three times more than conventional systems and can take 10 years for the lower cost of wood-fuel to pay back the investment.

4

A Champion. The daily and yearly operations, maintenance, and fuel supply management are not for everyone. The most successful projects have one person who is committed to making things work and to figuring things out when they don't. Don't have a champion? Don't expect success.

5

A High Energy Bill. The potential savings wood-fueled systems promise can only be met if your need for energy is significant. Facilities with year-round need for heat like swimming pools, health facilities, and prisons are ideal!

Flexible Energy Communities

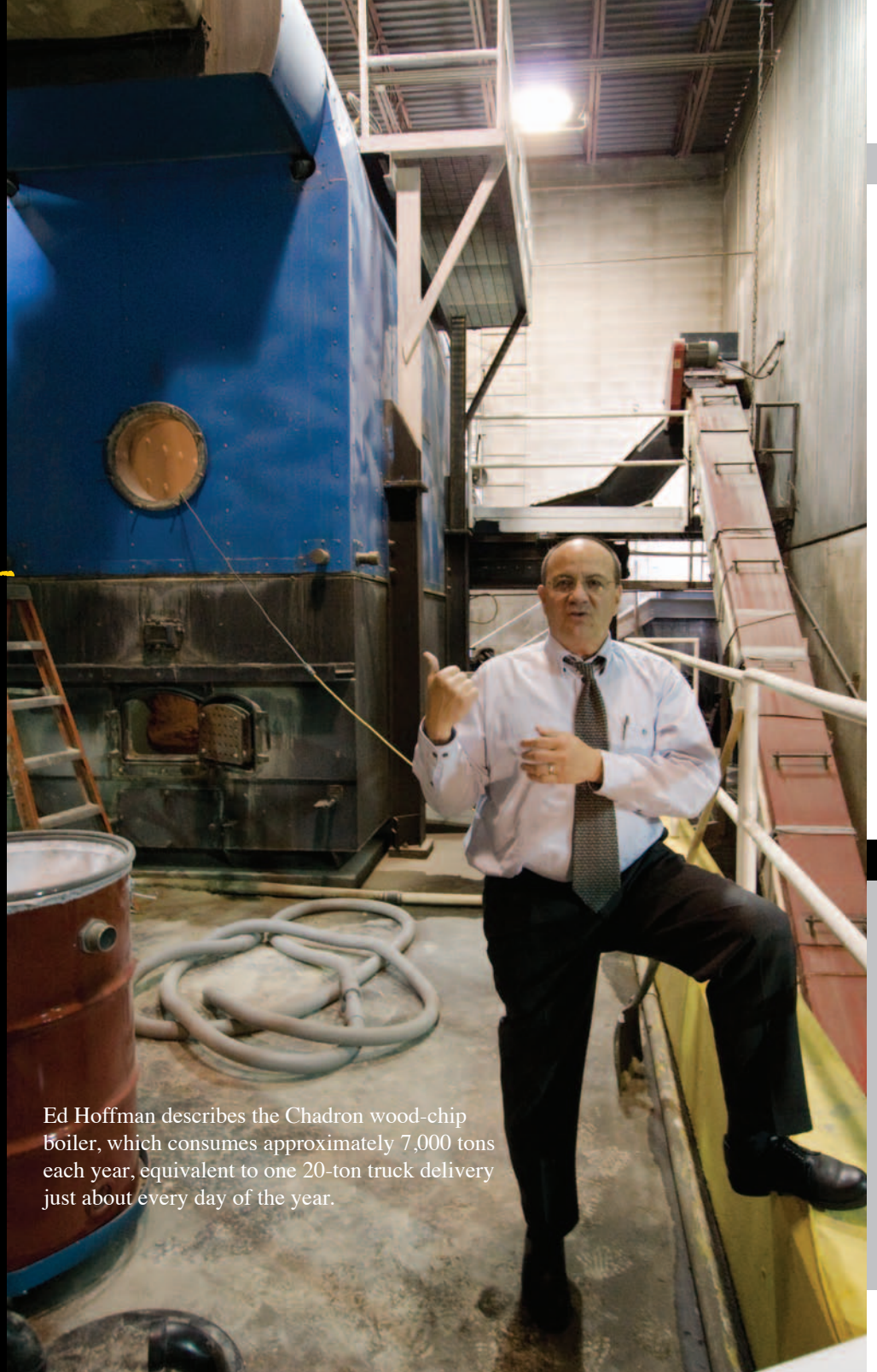
A community that prepares their new and existing buildings for an uncertain energy future by:

- *Planning and designing so that new energy systems can be easily added when those systems become economically attractive.*
- *Purchasing and installing new energy equipment when the time is right for your community.*
- *Minimizing energy use while maximizing comfort and utility.*

The Flexible Energy Communities Initiative (FLECI) is a design-assistance program sponsored by the U.S. Forest Service, the Bureau of Land Management (BLM), and the Colorado Wood Utilization and Marketing Program (CO-Wood) to help your community prepare for emerging new energy technologies including wood-fuel, solar energy, geoexchange (geothermal), biogas, and fuel cells.

This funded design-assistance program can help you make your building "woody biomass ready", often at no increase to your construction costs!

visit: www.fleci.org



Ed Hoffman describes the Chadron wood-chip boiler, which consumes approximately 7,000 tons each year, equivalent to one 20-ton truck delivery just about every day of the year.

Chadron State College, Nebraska

For more than 15 years, Chadron State College in Nebraska has been heating its campus of 2,800 students with wood chips from local forests. Keys to success include: a solid design, proven technology, reliable local supply of wood chips, and the personal commitment of Ed Hoffman, now a vice chancellor for the Nebraska State College System.

A local, family-run business supplies chips for the campus, and their kids now attend the very college they help heat. The moisture content of the chips varies over the year, so the contract is based on the energy content, not weight.

Ed says it took about four years before the operation ran smoothly. Now, it works so well that they recently added an absorption chiller to cool their buildings in the summer using the steam from the wood-chip boilers. The more they run the boiler, the more money they save, and the less carbon they emit.

The Numbers

- *24 buildings*
- *1,100,000 square feet*
- *9-MMBTU/hr wood-chip boiler system.*
- *Including operations and maintenance, estimated savings are more than 30% over natural gas at $10/MMBTU.*

Boulder County, Colorado

Boulder County's new 120,000-square-foot Parks and Open Space complex in Longmont, Colorado, is an excellent example of where wood really works. All the right conditions for success existed:

- The county manages more than 18,000 acres of forested land. Their ongoing fuel-reduction and restoration efforts are capable of easily meeting their fuel needs.
- They designed from the ground up.
- The county and community strongly value environmental stewardship and appreciate the zero-carbon impact of wood-fuel.
- A project champion (or two, or three) who wanted to make it happen.
- The team started the design just as natural gas prices began rising.

Starting with a blank slate, the design team chose to implement a centralized district energy system using hot water distribution. This gives the site the most flexibility to adapt to a changing energy future. All the changes can be done in one location, taking advantage of scale for both equipment costs and operation and maintenance.

Depending on natural gas prices and the variable costs of chips, the project is estimated to have a simple payback of less than 10 years.

The Numbers

- *Six buildings*
- *120,000 square feet*
- *3.3 million BTU/hr wood-chip boiler*
- *650 tons/year of dry chips (20% moisture equivalent)*
- *Depending on natural gas prices, a simple payback of 8 to 20 years is expected*
- *Video and brochure can be found at Colorado Governor's Energy Office: www.colorado.gov/energy/renewables/Biomass.asp*

Our Friend the Wood Pellet

Wood pellets are the ideal fuel for small to medium applications—the most promising wood-fuel for buildings in the "messy middle."

Pellets are sometimes referred to as a ***refined wood-fuel***—much as gasoline is a refined fuel from crude oil. Size, shape, moisture, and ash content are very consistent between vendors and bags (and, increasingly, truck loads). This uniformity allows reliable, affordable automatic fuel handling from an outdoor bin or silo to the indoor boiler or furnace.

This uniformity also allows combustion systems to be highly tuned, making pellet systems very clean and efficient.

Wood pellets are also known as a ***densified biomass***, where most of the water and air have been squeezed out, leaving just wood energy. Pellets have nearly twice the energy per pound as typical cordwood, and occupy only about one-third the volume. This makes long-distance transportation affordable. In fact, North American pellets are routinely shipped to Europe.

While manufactured wood pellets can be used in simpler systems, this naturally comes at a cost. Wood pellets cost about twice as much as wood chips for the same amount of energy. For medium and small systems, this is a good trade-off.

Wood pellet manufacturing plants are a significant investment. An entry-level factory costs approximately $3 million, and upwards of $10 million is not unusual.

This pellet boiler heats...

...this physical therapy pool

U.S. Representative John Salazar opens the first bag of 100% Colorado wood pellets in October 2006.

Wood chips await drying

Dryer is fueled with scraps and defective pellets

Key Points

- *Uniform size, moisture, ash content, and energy content*
- *Simplified fuel handling*
- *Tuned for clean combustion*
- *About twice the cost of wood chips*
- *Small pellet mills make 4 tons per hour and cost several million dollars.*

Pellet mill open for cleaning

Pellet mill open for business at 4 tons per hour

Grain silo ready for first batch of wood pellets

Making Wood Pellets

Cordwood Boilers

The Numbers

- *Cost: $20K to $60K*
- *Heat output: 100,000 to 900,000 BTU/hr*
- *Fueling cycle: Stoke one to three times a day*
- *Payback: 3-5 years against propane and heating oil*
- *Air quality: very clean to very dirty.*

Cordwood

Simplicity and great economics make cordwood boilers increasingly popular around the country. Cordwood—firewood size or a bit bigger—from on-site or local forest management projects is often free!

If you have a home or small building to heat and live near a forest that needs thinning, these systems have very good economics. If you have a hot water (hydronic) heating system, the economics are even better.

Buyer beware! There is a huge difference between clean units and dirty units. The EPA has recently released voluntary guidelines, but they have a ways to go.

If you follow the manufacturer's recommendation, these units can be very low emitters of smoke—much cleaner than the cleanest of fireplaces. But, if they are mishandled, these units can be very dirty. Some irresponsible owners have used their boilers as an incinerator, burning household garbage, and even tires!

Wood-heating pioneer Dick Cook designed and built the boiler shed and very convenient wood handling system for his 300,000 BTU/hr boiler. Dick has been testing a variety of wood drynesses and species.

The smoke coming out of the chimney is from excessively dry wood not recommended by the manufacturer (or Dick). But even with the wrong wood, the system is virtually smokeless after the initial 5-15 minute start-up cycle.

As part of their hands-on Sustainable Energy Certificate program and the college's efforts to manage rising energy costs, Santa Fe Community College installed this 300,000 BTU/hr boiler and housed it in a shipping container.

The boiler features an integrated 1,500 gallon water jacket to store heat. This allows the wood to be burned rapidly and cleanly at an optimum rate, independent of how much heat is needed. Need more heat? Load the fire box more frequently. Less heat? Less often. No smoldering fires here!

While the larger units really need their own shed or outbuilding, smaller European boilers, like this 130,000 BTU/hr unit, can fit nicely in your basement. Of course, not all basements are set up to haul in firewood.

A 650 gallon hot water tank (silver tank) is the recommended way to store several days' worth of energy.

Dave Followill can fire his boiler once a week in the summer to provide his home with domestic hot water.

Let the Burner Beware...

$30 per ton? Is that a green ton, a bone-dry ton, or something in between?

30% moisture content? Is that dry basis or wet basis?

Moisture Content Formulas (important!)

Wood from a freshly cut live tree is "green wood." Its energy content varies dramatically. Wood that has been placed in an oven until all the moisture is removed is called "bone-dry" or "oven-dry" wood. Its energy content is very consistent.

$$\text{Dry Basis Moisture Content} = \frac{\text{Initial Weight} - \text{"Bone-Dry" Weight}}{\text{"Bone-Dry" Weight}} \times 100\%$$

$$\text{Wet Basis Moisture Content} = \frac{\text{Initial Weight} - \text{"Bone-Dry" Weight}}{\text{Initial Weight}} \times 100\%$$

The word "energy" in normal conversation is used fairly loosely with a variety of meanings. But in engineering and science, energy has a very precise, specific meaning: "the capability of doing work; different forms of energy can be converted to other forms, but the total amount of energy remains the same."

In the case of wood, that work could be warming your home or boiling water to make steam that spins a turbine that, in turn, runs a generator that produces electricity. These two forms of energy—heat energy to warm your home and electrical energy to light a light bulb—can be numerically measured and compared.

In the United States, heat energy is typically measured in BTUs, or British Thermal Units (today, the British use the metric counterpart, the Joule). One BTU is defined as the amount of heat energy needed to raise 1 pound of water 1 degree Fahrenheit. One BTU is about the amount of energy released by a single kitchen match, so it takes a lot of BTUs to do anything useful. Heating your home takes about 1 million BTUs each day in winter in many parts of the country.

How much energy is in a ton of wood?

It depends. Wood with all water removed (called "bone-dry" or "oven-dry") contains about 8,000 BTUs per pound—or 16 MMBTUs (MMBTU means 1 million BTUs) per bone-dry ton. This is nearly the same for all wood species. Wood, however, usually contains water, often a lot of it. And how much water the wood contains is referred to as its moisture content. Moisture content is very important in determining the amount of energy and economic value in a ton of raw material.

The moisture content depends on many things: the tree species; the length of time since the tree was felled, and the humidity of the climate where the wood is stored. Moisture content is measured in percentage (%), but there are two very different definitions—dry basis and wet basis (see calculations on sidebar). Dry basis is the most common method, but this needs to be clearly stated.

When felled, more than half the weight of the green wood can be water. Using the common dry-basis definition, the moisture content can actually be higher than 100%.

Energy Content of Some Common Fuels

Fuel	Energy Content		Cost per Unit		Cost per MMBTU
Wood Chips	about 8,000 BTU	per bone-dry pound	$0 to $100	per bone-dry ton	$0 to $6.40
Wood Pellets	8,000 BTU	per pound	$140 to $250	per ton	$8 to $15
Electricity	3,413 BTU	per kWh	$0.05 to $0.15	per kWh	$14 to $44
Natural Gas	1,000,000 BTU	per MMBTU	$5 to $15	per MMBTU	$5 to $15
Heating Oil	139,000 BTU	per gallon	$2.00 to 2.60	per gallon	$14 to $19
Propane	91,000 BTU	per gallon	$2.00 to $2.90	per gallon	$22 to $32
Coal	8,800 - 13,000 BTU	per pound	$12.00 to $70.00	per delivered ton	$0.70 to $2.40

These numbers are derived from U.S. Department of Energy statistics for 2005-2006, your mileage may vary.
MMBTU = 1 million BTUs.

If you are buying wood for its energy content, you will want to know the equivalent bone-dry weight. In fact, many good supply contracts are written in terms of the amount of energy, not the physical weight or volume. However, if you're hauling freshly cut wood out of the forest, your costs will be determined by the actual, or green tonnage weight.

Finally, when burning green wood, much of the wood's energy will be used for evaporating the moisture. Most systems cannot recover this heat; it just goes up the chimney as steam.

Electrical energy is measured in kilowatt-hours (kWh). One kWh is the amount of energy a 100-watt light bulb uses every 10 hours a or 1,500-watt blow-dryer uses in 40 minutes. A typical house uses around 700 kWh in a month. A 1-megawatt (MW) power plant can power about 1000 homes.

You can mathematically convert between heat energy and electrical energy. One kWh is about the same amount of energy as 1/2 pound of bone-dry wood. However, the most common technology used to convert heat energy to electrical energy—the steam turbine—is only about 35% efficient. So, to get 1 kWh worth of electricity, you need about $1^1/_2$ pounds of wood!

There are several key issues that often make it difficult for wood to be used as the primary fuel for electrical generation.

- **Scale.** Most power plants in the U.S. are between 100 MW and 2,500 MW. This is mostly because the cost of operating a power plant doesn't change very much between a small plant and a large plant. You still need a 24 X 7 trained/skilled workforce.
- **Fuel costs.** About 50% of U.S. power plants use coal. Low cost, long-term contracts at about $1.20/MMBTU are not uncommon. This is equivalent to wood at $20 per bone-dry ton delivered and guaranteed for many years.
- **Fuel uniformity.** Coal plants are typically designed to be maximally efficient when using coal from a particular mine. The properties of the coal are very consistent. Wood, on the other hand...

How Much Can a Forest Sustainably Yield?

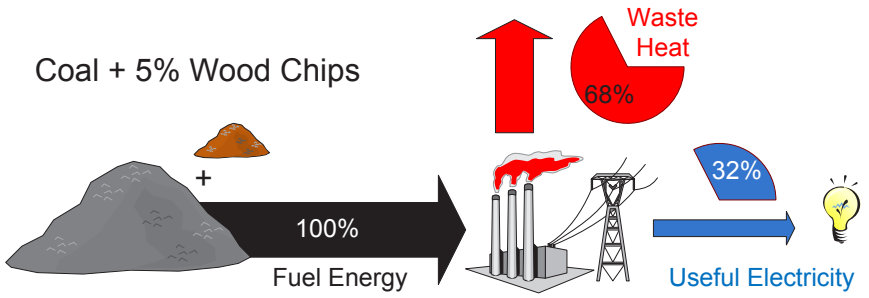
There is no single answer to this question. You will need to contact your local forest experts. However, as a rough estimate, forest restoration projects in the Intermountain West use 10 bone-dry tons per acre as a rule-of-thumb. In an area where ongoing management is planned, a 20-year re-entry cycle of vegetation treatment is common. Therefore, on average, one-half of a bone-dry ton per acre can be sustainably removed from the forest.

A 2,100 MW coal-fired (not co-fired) power plant in Sweetwater, Wyoming, generates enough energy for about 2,000,000 homes!

Co-firing with wood chips...

Co-firing usually means mixing a small percentage of wood chips with coal. Technically, this is typically straightforward, but the wood must be very cheap. Why?

- ◊ Coal is generally the cheapest fuel available.
- ◊ Coal supply contracts routinely exceed 15 years. This is difficult for wood to compete with.
- ◊ For a given mine, coal is very uniform in energy and chemistry. Wood is not.



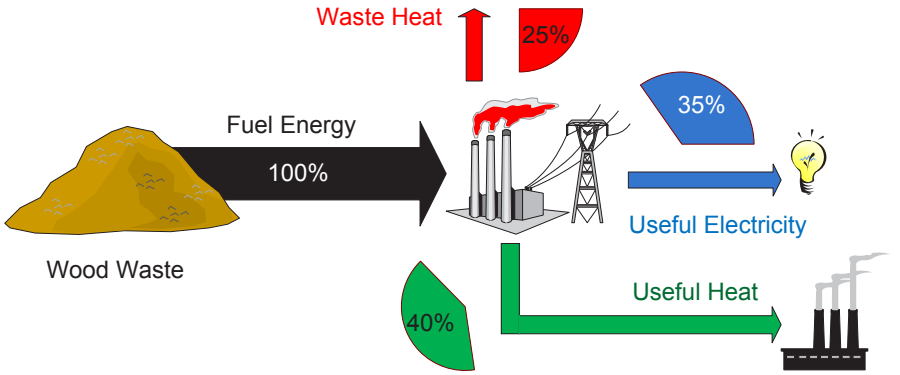
Co-fired, coal-fired 38.5 MW power plant in Cañon City, Colorado. This is the first in the country to qualify the biomass for Renewable Energy Credits (RECs).

Cogenerating with wood chips...

Cogeneration, cogen, or Combined Heat and Power (CHP), means using the energy released from burning the fuel to simultaneously generate electricity ***and*** heat. While conventional coal plants only utilize a third of the fuel's energy, CHP systems can easily exceed 70%. To make these systems work economically, you generally need:

- ◊ A large heat load (industrial customer or district heating)
- ◊ Very cheap fuel (waste material on-site)

Paper mills are excellent examples of cogeneration, meeting both of these conditions.



Large-scale, wood-waste-fired cogeneration mill on the Olympic Peninsula, Washington.

Wood-chip boiler building that heats the Darby School, the first Fuels for Schools project in Montana.

Rick Scheele – Darby Mayor, School Maintenance Supervisor, and local biomass "champion" – inspects a bad load of wood chips and explains how to avoid this problem.

The Team...

It's not what you know, but who you know...

There is no need to travel this road alone. Many communities have successfully installed wood-fueled systems and are willing to share what they have learned. But, perhaps the most important thing they will tell you is, *get yourself an experienced guide.*

COLORADO GOVERNOR'S ENERGY OFFICE, GEO, through its Woody Biomass Program and coordination of the Colorado Biomass Working Group, can assist with facility heating projects throughout the state. GEO staff and Working Group partners can help with overall project design, supply issues and possible funding mechanisms.

www.colorado.gov/energy

BIOMASS ENERGY RESOURCE CENTER has been on the team of nearly every public wood-fueled heating project in the country. You can immediately tap into their expertise through their publications and Web site. And when your team is ready for the heavy lifting, they can provide first-rate and affordable consultation.

www.biomasscenter.org

FUELS FOR SCHOOLS concept is simple: reduce heating bills at schools by utilizing low- or no-value forest waste. Their mission: help make your wood-fueled project a success. Their experience, candor, and successful examples will help guide your first wood-fuel project. As of October 2006, six wood-fueled systems have been installed, with 11 more on the way!

And, they are not just for schools anymore. They have expanded their program to include all public buildings that can benefit by using wood-fuels. Check out their Web site, then give them a call.

www.fuelsforschools.org







Colorado Wood Utilization & Marketing Program

Governor's Energy Office

NREL National Renewable Energy Laboratory
Innovation for Our Future

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