11-1981


George M. Turner
University of Kentucky

Click here to let us know how access to this document benefits you.

Follow this and additional works at: https://uknowledge.uky.edu/aees_reports

Part of the Bioresource and Agricultural Engineering Commons

Repository Citation
Agricultural Engineering Energy Series. 17.
https://uknowledge.uky.edu/aees_reports/17

This Report is brought to you for free and open access by the Biosystems and Agricultural Engineering at UKnowledge. It has been accepted for inclusion in Agricultural Engineering Energy Series by an authorized administrator of UKnowledge. For more information, please contact UKnowledge@lsv.uky.edu.
Energy Resource Series for Youth and Adult Energy Programs

9. Wood

by
George M. Turner
Extension Specialist for Agricultural Engineering

Department of Agricultural Engineering
University of Kentucky
Lexington, Kentucky
Preface

In the near future the United States will need energy from as many different sources as possible to furnish the total amount needed. Wood has two big pluses going for it. It is renewable, and it is fairly clean in the combustion process.

It is important that we learn all we can about the growing plants that could furnish a segment of our energy needs. For this reason, the conversion of sunlight into stored chemical energy is described in some detail in this publication.

This is the ninth publication in a 12-part energy resource series designed for the serious adult and student with an interest in the energy situation. Each publication in the series examines a different energy source and considers the advantages and disadvantages associated with its use.

When necessary, diagrams and/or tables are used to clarify or elaborate upon information found in the text. Questions with answers are included at the end of each publication so that you can test what you have learned.

The author wishes to thank Larry W. Turner and Linda Bach of the Department of Agricultural Engineering, University of Kentucky, for reviewing the text.

The Energy Resource Series for Youth and Adult Energy Programs includes the following publications:

AEES-21 Energy Overview
AEES-22 Definitions
AEES-23 Oil and Gas
AEES-24 Coal
AEES-25 Solar
AEES-26 Wind
AEES-27 Nuclear Fission
AEES-28 Nuclear Fusion
AEES-29 Wood
AEES-30 Water
AEES-31 Geothermal
AEES-32 Alcohol
Contents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Bio-Fuels</td>
<td>4</td>
</tr>
<tr>
<td>Photosynthesis</td>
<td>4</td>
</tr>
<tr>
<td>Bio-Energy Chain</td>
<td>7</td>
</tr>
<tr>
<td>A Wood Energy Plant</td>
<td>8</td>
</tr>
<tr>
<td>Wood Heating in the Home</td>
<td>9</td>
</tr>
<tr>
<td>Built-In Fireplaces</td>
<td>9</td>
</tr>
<tr>
<td>Freestanding Fireplaces</td>
<td>9</td>
</tr>
<tr>
<td>Consider Chimney Height</td>
<td>10</td>
</tr>
<tr>
<td>The Economics of Wood-Burning Fireplaces</td>
<td>10</td>
</tr>
<tr>
<td>Questions</td>
<td>11</td>
</tr>
<tr>
<td>Answers</td>
<td>12</td>
</tr>
</tbody>
</table>
9. Wood

Introduction

In AEES-25 Solar, it was explained that on each clear day a quantity of energy equal to 56,000 times the annual energy consumption of the United States comes toward the earth from the sun. The first thing that happens is that about half of this energy is reflected back into space. Of the remaining quantity, part is absorbed and re-radiated to space and some goes to vaporizing water.

Research indicates that approximately one-tenth of 1 percent of the original energy enters into the reaction with green plants in the photosynthesis process. In the United States, a horizontal surface 1 meter square receives an average of 200 watts of energy when the sun shines. We will now take a look at this energy source and how it is put to use.

Bio-Fuels

Wood is a bio-fuel. This means that it comes from living things. Lawn grass, field crops and garden plants and flowers are all in the bio-family of living things. In fact, there is no difference between the wood of today and fossil fuels of aeons ago, such as coal and oil except time. Millions of years ago all fossil fuels were lush green plants, thriving on nutrients and moisture in the earth and the photosynthesis process. These have long since died but have been preserved beneath the surface of the earth. Actually, the wood of today and the fossil fuels of aeons ago trace their origin to energy from the sun. The plant’s tissue is a storehouse of some of this energy. The energy remains stored until plants are eaten, burned or decayed, thus releasing the energy. Decay results when microbes and fungus digest the plant tissue.

Throughout history man has used bio-fuels as a source of heat energy. When fire was discovered, wood and any other dry plant or animal tissue were used as the fuel. But compared to the radiant energy collectors, water turbines and wind generators, plants are very inefficient users of solar energy. One reason for this inefficiency is the short growing season of plants. On the other hand, living plants are the only earthly mechanisms that can directly convert the radiant energy from the sun into living tissue for storage.

The conversion of sunlight, through many steps, into chemical energy for storage is a second reason for inefficiency. Man has not yet devised a method of artificial photosynthesis. This does not mean that it will not be done. The closest that man has come to matching the process of photosynthesis has been with silicon cells that produce electricity and then store it as chemical energy in batteries. This overall process is also inefficient. Apparently, the storage of energy is the big problem of most energy systems.

Photosynthesis

You should realize what a vital function the photosynthesis process plays, and has played for past aeons of time, in our present living process. Living plants provide the right balance of oxygen to the atmosphere.

Animals eat plant food including grass, fodder and grain. Man in turn consumes the meat of animals or other animal products, such as animal milk and eggs. Thus, the photosynthesis process furnishes us with oxygen, food and most of our energy or fossil fuels.

Every part of a tree or living plant offers an extraordinary study in exactness and ingenuity of relationships. From the microscopic “hair” roots, which one can actually watch grow, on up through the trunk, and out through the multitude of branches to the leaf, plants offer a person a lifetime of intensely interesting study. Each part depends on all the others, and they all work in a unison that overshadows the harmony of a great orchestra.

But of all the parts of a living plant, the leaf has been of greatest interest to man. History testifies to man’s long realization that the leaves of living plants are the key to energy and life on earth. Hundreds of years ago man did not have the sophisticated instruments that we have today. But that did not stop plant researchers from imagining, and fairly
closely too, what was going on. Any library or bookstore will have a great reservoir of information on plant researchers' observations and theories through the ages. These make interesting reading.

Many junior and senior high school science books have excellent, illustrated discussions of plants and the function of their leaves. Most encyclopedias also cover the photosynthesis process. These, along with the other publications in this series, help reveal the vital link between photosynthesis and the living process.

There are some seemingly vital things that man could learn to live without, such as natural gas or crude oil (and in the next 25 to 50 years this is quite probable). But just suppose that all the plants around the world were defoliated and remained that way. Soon, all animal life, including humans, would perish. Animal life could continue for a while on the residual food stored in plant tissue and on what oxygen remained in the atmosphere. But even though the earth kept turning, the sun shining, and oil, gas and coal remained in the earth, animal life would cease to function, whether from food starvation or suffocation. Even combustion-type engines would not work for lack of oxygen. Therefore, the leaf plays a vital part in our lives.

The process of the leaf using sunlight to manufacture food is called photosynthesis. The dictionary defines photosynthesis as "putting together with light." In Figure 1, a greatly enlarged sketch of the cross section of a leaf is shown. Actually, there is quite a lot of space inside a leaf. The inside of the leaf is the heart of the living universe. The upper surface, the roof and lower surface, the floor, are kept apart by columns of cells forming a space in a way similar to the great caverns of underground coal mines and rock quarries.

Fig. 1.—A greatly enlarged diagram of the cross section of a leaf. The physical mechanism of the tree keeps the leaf topside up and oriented toward the sun.

The upper portion of the cell column consists of palisade cells, and the lower portion consists of spongy cells. The palisade cells form a nearly solid layer, while the spongy cells have quite a lot of space between them. In this space are found atmospheric air and water. The inside surface of the palisade cells is coated or sprinkled with a thin layer of much smaller cells called chloroplasts. Inside these jelly-like chloroplast cells are remarkable molecules of a green-colored pigment called chlorophyll. The spongy base cells have a small quantity of chlorophyll also. It is this green-colored pigment that gives leaves their green color.

Plant scientists have found that the composition of the majority of the chlorophyll molecules is $C_{55}H_{72}MgN_{4}O_{5}$. The cell structure of the roof of the leaf is fairly transparent, and so are the walls of the palisade cells. On a clear day, sunlight floods these cells, like rooms built with skylights in the ceilings, and interacts with the chlorophyll molecules.

Water from the roots and carbon dioxide from the air are gathered by the spongy cells and are forced by the energy in sunlight to form glucose inside the palisade cells. Oxygen is given off and returns to the atmosphere through the stomate. Water evaporates from the leaf and leaves as vapor, leaving through the stomate. This action causes the pumping force to bring water from the roots to the leaf. There are thousands of these openings in each square inch of leaf. Plant scientists estimate that it takes 50 leaves of an apple tree to make one apple.

The interaction of sunlight and the chlorophyll molecule is the basis of photosynthesis; thus chlorophyll is the basis of plant life and in turn, is the basis of animal life on earth.

In AEES-22 Definitions, a description of radiant energy was given under Heat Translation. Heat, light, and radio waves, etc., are forms of electromagnetic massless particles called photons. The size or magnitude of the quantity of energy each photon can convey (quantum) is a function of its frequency of vibration as it travels from the source that emitted it.

Figure 2 shows the frequencies of the ultraviolet (UV), visible and infrared (IR) light portions of the entire electromagnetic spectrum. This figure also shows that the chlorophyll molecule absorbs photons vibrating at frequencies in the blue-violet and red-orange ranges but rejects, that is reflects, those in the green range. This is the reason for the green color of the chlorophyll.

Energy in electromagnetic radiation is in the form of photons vibrating perpendicular to the directions of travel, and they travel at the speed of light, 186,000 miles per second or 300,000 kilometers per second. Photons, at this rate, travel from the sun to the earth in about 8 minutes. Photons in
Fig. 2.—The relative energy absorption of chlorophyll molecules. This portion of the electromagnetic spectrum covers visible light. The frequency bands or channels that constitute the colors bracket the color names. Understand that there is no definite dividing line between colors, but that they all blend gradually into each other. The numbers at the top give the frequency of vibration of photons at this point of the spectrum, in cycles per second, increasing from left to right. The series of numbers at the bottom give the wavelength at this point of the spectrum. Several different units are listed that are in common use today, so that a comparison of each can be made.

the upper fringes of the blue range have about twice the energy of photons in the lower end of the red-orange range. This is because the frequency is about double. As an example, it may be assumed that while a red photon passes an object, say an electron, it may hit it once, but a blue photon passing the same object at the same velocity (the speed of light) would hit it twice. Plant scientists think that the photons in the blue-violet portion of the spectrum are responsible for most of the work or energy of the photosynthesis process.

Now the same thing happens when a photon strikes an electron of the chlorophyll molecule. If the photon has enough energy, it can knock the electron completely away from the molecule. Two things are now apparent. A moving electron is an electric current. Having it dislodged from a molecule changes the electrostatic valence or attractive forces of the molecule or of the atoms that make up the molecule. This results in quite a complex chain of reactions. The chlorophyll and other enzymes acting as catalysts eventually result in the cracking of the water and carbon dioxide molecules in the rooms of the leaf. The overall equation is:

\[
\text{sunlight and the chlorophyll molecule } \rightarrow \text{carbon dioxide and water}
\]

In the section “Combustion” in AEES-22 Definitions, an equation similar to this is given for the burning of a hydrocarbon fuel. As the molecule of \( \text{C}_6\text{H}_{12}\text{O}_6 \) (gasoline) cracks and the parts join with oxygen to form carbon dioxide and water, energy in the form of heat (highly excited molecules) is given off. Each gram of carbon dioxide gives 2,100 Calories, and each gram of water gives 3,800 Calories. In the above equation the reverse is happening, similar to charging a battery. It takes the same energy per gram to check the smaller molecules of carbon dioxide and water and form the larger molecule of glucose, plus some extra energy for inefficiencies.

Energy is stored in the glucose molecule. This is known as chemical energy. The attraction forces holding the atoms of carbon, hydrogen and oxygen together in the glucose molecule are not as strong as the attraction of carbon for oxygen or hydrogen for oxygen. It does take some force, however, to break up the glucose molecule. When this happens, the pieces will automatically form carbon dioxide and water when provided with plenty of oxygen, such as in combustion. This is because the attractive forces are greater.

Here is an analogy. Compare the chemical situation to objects like stones. Gather a bucket of small stones, rocks or gravel. Use a mechanical winch and human effort to raise the bucket 50 feet.
The bucket of stones now has increased potential energy. If you were to tie the rope to other smaller objects, each would be lifted as the larger bucket came down. If the bucket were released and allowed to fall, crashing into the earth, an attempt could be made to harness the noise and heat generated by the impact.

In similar fashion, it takes energy to split or crack the water and carbon dioxide molecule and knock a high energy possessing electron from the chlorophyll molecule; thus forcing together water and carbon dioxide in the form of a sugar molecule. It is like raising the parts to a higher location, thus, giving them greater potential energy or like winding up a rubber band to power a model airplane. The energy to form the sugar molecule came from the vast number of high energy photons that came directly from the sun. In this way, actual forces (electrostatic) are stored up and can be released to fall to lower levels and give up energy (heat) when they collide. Biochemists and nuclear engineers measure these forces in electron volts (ev) and predict the heat energy needed or given up in various reactions.

In the case of fossil fuels, the energy has been preserved for aeons. You can trigger the release of portions of this material and use it at any rate. For instance, if a greater quantity of heat from a wood stove is desired per hour, more pieces of wood can be added per hour. The triggering mechanism occurs when both the vaporization and kindling temperature are reached, thus breaking up the large hydrocarbon or sugar molecule. The parts fall toward oxygen in the air because they are attracted by electrostatic forces to form carbon dioxide and water again.

Now, take an example of a large rock atop a high cliff. If you could push the rock over the edge, gravity would do the rest. It takes some effort to dislodge the rock from the cliff, so it will be free to fall to the bottom. This is the way it is with a glucose molecule. It takes some effort or energy to dislodge atoms that are resting together, similar to the rock resting on top of the cliff. But when they are forced apart, they move to the greater attraction of carbon to oxygen atoms, and hydrogen to oxygen atoms, just like the rock to the attraction of the earth below.

These are analogies. Because they are analogies, these examples may raise more questions than answers for some people. The object is to show that chemical energy consists of electrostatic forces or positive and negative charges. The nuclear physicist and biochemist use the same mathematical formulas to solve problems as are used by the mechanical engineer. The objects they work with are incredibly small, but the number of objects and the velocities are incredibly great. The results are the same.

Bio-Energy Chain

Try to imagine a worldwide mechanical system built on the bucket and rope method. Theoretically, it can be done, although it would be extremely cumbersome. Immediately you can see that lots of people would be needed to keep winding up the winches. You also can see that it would take more input energy than you could get out.

You can mentally grasp the great amount of effort it would take to raise enough buckets fast enough to keep all the electric generators and vehicles going. You would keep pouring this energy in, but it would not come back. Where does it go?

Ultimately, the use of energy results in heat. This heat is radiated to space, and as far as the earth is concerned, it is lost forever. This does not violate the laws of thermodynamics. This heat is still in the universe. However, it is in a form and place that man cannot regather and use.

Energy, like gravity, as far as we are concerned, is a one-way street. Energy flows one way. It comes by in small bundles (quanta), passes on, and never returns. Humans use an incredibly small portion of the total flow. There must be an immense source to keep the system going. That is where the sun fits into the picture. Even though it changes millions of tons of mass into energy (photons), each second it has such a great total mass, that percent-wise the exchange is extremely small. But even the sun is finite. At some time in the far distant future, its mass loss will become significant; the sun will change and cease to emit sunlight.

By nature, the energy system of the universe is very inefficient. Look at Figure 3. The energy output of the sun is great but, as different steps are included, only a small amount of the total flow is captured or harnessed for useful work on earth.

The living plant mechanism is similar. There are many steps involved in getting the energy of the photons that strike a chlorophyll molecule into the human body tissue to enable humans to be active at what they want to do. The source of supply of these photons is immense and constant. This is actually what keeps life, as we know it, on the move.

It is useful to know something of the overall effect of the bio-fuel chain. Assume that on an acre (208 feet square) of the earth's surface in Kentucky, approximately 8 billion Btu per year of radiant
energy comes from the sun. A very small fraction of this is captured by living plants, around 1 percent or 80 million Btu. The rest is lost to plant use by reflection, radiant heat and evaporation of moisture.

Of the 80 million Btu, some must be consumed in the plant metabolism process, just as an animal uses energy in staying alive and producing body heat. Large trees lift 100 to 200 gallons of water each day. It is estimated that about 25 percent of a plant's energy goes for its living process alone. Only about 60 million Btu are converted into plant tissue.

Animals grazing on pasture grass waste about half of the grass for various reasons. This cuts the 60 million Btu to 30 million. One meat animal will use 90 percent or more of the plant food in its own living process or metabolism. The plant food must build and maintain a bone structure to carry the animal's weight, hide or skin for the animal's body, as well as energy for digesting the plants, furnishing body heat, and pumping hundreds of gallons of blood through the circulatory system. A large percent of the plant material passes on through the animal's digestive system as manure. There are some inputs of energy from other sources like the atmosphere (breathing) and drinking water. This must be summed up in the total process.

When an animal is slaughtered, a large percent of the carcass is nonedible by humans. In fact, less than 10 percent of the animal is consumed.

The efficiencies of each step of energy transformation in the food chain just discussed are multiples, not additives. The following steps show what happens to the original 8 billion Btu reaching the acre of soil.

\[
\begin{align*}
8,000,000,000 \text{ Btu} & \times 0.01 = 80,000,000 \text{ Btu received by plant leaves} \\
80,000,000 \text{ Btu} & \times 0.75 = 60,000,000 \text{ Btu converted to plant tissue} \\
60,000,000 \text{ Btu} & \times 0.50 = 30,000,000 \text{ Btu eaten by beef animals} \\
30,000,000 \text{ Btu} & \times 0.10 = 3,000,000 \text{ Btu converted to animal tissue} \\
3,000,000 \text{ Btu} & \times 0.10 = 300,000 \text{ Btu ingested by humans}
\end{align*}
\]

Rather than listing these steps in table form, the efficiency of the entire process or food chain could be on a single line since efficiencies are multiples:

\[
8,000,000,000 \text{ Btu} \times 0.01 \times 0.75 \times 0.50 \times 0.10 \times 0.10 = 300,000 \text{ Btu}
\]

Some plants have the inherent capability of a higher production efficiency than others. The young plants of most species fall in this category. From this, one would deduce that tree species that gain rapidly during the first few years are more desirable for a woodlot. If a single crop is confined to a small acreage year after year, the area becomes burdened with disease and parasites, which make management more difficult. In spite of these difficulties, a well-managed tree farm may produce some useful energy. It would take place in the following way provided all the factors allowed it to work.

**A Wood Energy Plant**

Assume that a large tract of land could be obtained, say 2,000 acres. Even if it is quite hilly, the trees could be planted and harvested. Agricultural engineers would have a big hand in designing the machinery and harvesting methods; forest scientists would devise the type of trees and the planting schedule.

Assume that major growth took place in four years so that one-fourth of the 2,000 acres would be harvested each year and consumed in the boilers. One could assume also that each acre would yield 5 cords of a rapid growing species under the right conditions and that each cord averages about 20,000,000 Btu. This is 100,000,000 Btu per acre, which totals 50 billion Btu per year.

A large electric generating plant only operates about 20 percent of the time at full capacity. It
would burn fuel at a high or maximum rate of only 20 percent of the year, or about 2,000 hours. The rest of the time it may be close to an idle rate or at least a greatly reduced rate. The 50 billion quantity divided by 2,000 hours is 25 million Btu per hour capacity. Since 2,600 Btu equal 1 hp, theoretically we have a plant that produces at a 9,600 hp per hour capacity. Putting this back into electric terms where each hp is equal to 746 watts, theoretically we have a plant that produces at a 9,600 hp per hour capacity.

Taking an overall average efficiency of 20 percent, from raw fuel (trees) to electricity on the line, this amounts to 1,920 usable electric hp to consumers. Putting this back into electric terms where each hp is equal to 746 watts, this plant puts out 1,432,000 watts or 1.43 megawatts. This is not a great deal of power as power plants go. Many small generation systems produce 15 to 25 megawatts. If one considers that the land might not be used for other crop production anyway, and that the energy source is renewable, this type of energy source may be feasible as one of many options. This type of fuel causes very little pollution and many such plants could be scattered around, putting the generation of energy close to the consumer.

Wood Heating in the Home

There is now a lot of interest in using wood for supplementing the main source of heat for the home. The main heating source may be natural gas, oil, coal or electric heat. Wood can be burned in homes with built-in or freestanding fireplaces, or in wood stoves. In any case, one thing is certain: plenty of free draft (combustion air) must be allowed or very disagreeable results appear.

With the great difference in temperature from the air near the fire to the outside, the airflow rate up a chimney (smoke stack) is about 500 feet per minute or about 5.7 mph. If a chimney is 8 feet in diameter, it has a cross-section area of 50 square inches or 0.35 square feet. Air moving through this at 500 feet per minute, creates a volume of 175 cubic feet per minute, or 10,470 cubic feet per hour. Each 13 cubic feet is about 1 pound of air, and it takes 0.24 Btu to raise 1 pound of air 1°F. The temperature of the air will be raised a total of 70°F. Multiplying all these together one has:

\[
\frac{10,470}{13} \times 0.24 \times 70 = 13,524 \text{ Btu per hour}
\]

This is the amount of heat taken from the room while a fireplace burns, if the room air temperature is maintained at about 70°F, and it is near 0°F outside. To get the open fireplace to draw satisfactorily and not smoke up the room, an opening, usually a window, must be provided to at least equal the cross-section area of the chimney.

Built-In Fireplaces

Built-in fireplaces can provide nearly all combustion air by means of an opening through the back of the combustion chamber to the outside. Fireplaces in basements and in interior walls cannot take advantage of this without elaborate duct work or must take air from the room for combustion. Some built-in fireplaces and most freestanding fireplaces, like the Franklin and pot belly stoves, have doors that when closed, limit the draft by letting combustion room air enter just below the grate through tiny adjustable openings. In addition, the freestanding type offers a lot more surface area that when warmed by the fire inside radiates heat to the room. In addition, room air is warmed by conduction when it comes in contact with the heat of the fire. This air in turn circulates, by difference in density, and carries heat to other parts of the room. This is known as convection heating.

Built-in fireplaces are usually of thick masonry construction. This becomes warm and radiates to the room, but built-in fireplaces do not have the inherent surface area of the freestanding types. The built-in fireplaces can have chambers built in the masonry, close to the combustion area. This allows room air to enter and be warmed and return to the room. This is also convection heating. This type of construction must be planned during construction of the fireplace because it is practically impossible to add afterward.

Freestanding Fireplaces

In the freestanding type, as heavy a material as possible should be used in the flue or smoke pipe, especially from the top of the stove to the ceiling as this gets extremely hot. Light or thin material will eventually burn through. Approved double- or triple-lined flues must be used through the ceiling and roof for safety. Regular galvanized-type smoke chimney pipe may be used outside, but an annual check should be made of this material to see that it has not rusted through.

To get maximum efficiency from a freestanding fireplace, such as the Franklin stove, you should operate it with the doors closed and the draft adjusted by the small opening at the bottom of the doors. Operated in this fashion there is less chance of smoke spilling out into the room. To prevent occasional spilling of smoke, make sure a brisk,
hot fire is going before adding new fuel. This may entail the use of lots of dry, easily combusted fuel. Splitting all large pieces will help immensely. After a few weeks or months of use, you will discover the best ways to manage the available fuel and the fireplace.

You can make several adjustments to the smoke pipe above the freestanding fireplace or stove to reduce the amount of heat exhausted and help it put more heat into the room. The dual, circle or doughnut technique is sometimes used. A 'tee' is attached to the stove outlet, then a circle or doughnut is fashioned of four elbows, and these are rejoined by a tee to the outside pipe just below the ceiling. The circle greatly increases the hot metal surface area, and it radiates heat back into the room.

To increase the exhaust pipe area, add a small drum or barrel in place of the circle of pipe. Inside the drum, place baffles to direct the hot gases back and forth against the outside surface. The outside of the barrel gets hot. Its large surface can radiate quite a lot of heat into the room.

You also can use several zigzags in the exhaust pipe between the stove outlet and the ceiling. If the ceiling is 8 to 10 feet in height, several extra feet of exhaust pipe can be placed in the room before exiting through the ceiling. Because of the unsymmetrically added weight between the zigs and zags, bracing may be needed to prevent collapse.

A note of caution is in order. With innovations such as these to increase heat input to a room, the temperature of the exhaust gases is lowered. Condensation of the creosote onto the inner surface of the smokestack is a possibility. The deposited creosote can catch fire under certain circumstances, resulting in a roaring fire in the chimney. Refer to AEN-20, at your local Extension office for more information on this subject.

Consider Chimney Height

The overall height of the chimney is important, mainly the part that extends above the roof. As long as the exhaust gases inside the smokestack are hotter than the air outside, the draft on the fireplace or stove will be active. But after these gases travel through 3 to 5 feet of thin pipe above a roof on a cold day the effect is minimized. The top of the chimney should be at a point where the prevailing wind blows horizontally. If the wind passes a tall house next door or a higher portion of roof on the same house, there could be a down draft on the chimney. This has a negative effect when the fireplace is operating.

No set height can be established for a given location, but much thought and study should be given to this factor. It may be that an entirely different location within the house will eliminate some of the exhaust problems. An extremely tall stack is not satisfactory from a construction standpoint, and also in regard to wind bracing and maintenance. Tall stacks tend to condense some of the gases into solids, such as creosote which sticks to the sides of the smoke pipe and becomes a fire hazard.

Although it is not necessary, a wind cap or shield is very helpful in preventing unpredictable down drafts caused by gusty winds whipping around adjacent buildings and roofs. This cap is very effective in eliminating most moisture from entering the stack. When installed correctly it will not adversely affect the operation of the fireplace. Effective caps can be made, or they can be purchased ready-for-installation from most hardware stores.

Information on fireplaces and chimney construction can be obtained from your local Cooperative Extension office; the agent can probably recommend several other sources of information as well.

An excellent publication, "Burning Wood," also can be obtained at your local Extension office. It contains many useful facts on different types of wood-burning devices and where to place them, and how to operate them for best efficiency and safety.

The Economics of Wood-Burning Fireplaces

Many people have purchased freestanding fireplaces and wood-burning stoves in the last few years. Also, many homeowners have contracted to have a built-in fireplace added to their present house. Before the energy crisis of 1973, fireplaces were intended for looks and occasional use for the aesthetic value of the open fire. The only requirement was that a fireplace did not smoke up the room when used.

Now serious thought is given to making the fireplace or stove an economic part of the heating system, usually as a supplement to the main system. What are the factors involved if the use of wood is to be big enough to effectively reduce the annual heating bill?

First of all, the annual heat requirement for the house must be calculated. This can be done by the following general rule. Annual heat requirement quantity, Q, equals the area of living space, times
the heat in Btu for each square foot, times the
degree days for your location. As a mathematical
formula this is:

\[ Q = A \times \frac{\text{Btu}}{\text{ft}^2} \times Dd \]

In Kentucky, the number of degree days is
between 3,000, along the southern border, to 5,000
along the northern border, an average of 4,000. This
is obtained by multiplying the number of days your
location is below a set standard of say 70°F. For
example, if you have 100 days of winter at an
average of 40°F, which is 30°F below the standard,
you multiply the deficiency of 30 \( \times \) 100 for 3,000
degree days that winter. A good average heat
requirement per square foot of floor space of a
house built in the last 15 years is 30 Btu per square
foot. If the house is exceptionally well-insulated,
the number could be much lower. If there is very little or
no insulation, it could be up to 45. In the following
element, 30 will be used.

Assume a single story house has 1,200 square
feet of living space. The formula becomes:

\[ Q = 1,200 \times 30 \times 4,000 = 144,000,000 \text{ Btu per year} \]

If you plan to reduce your annual conventional
winter fuel need, Q, by one-fourth and supplement
this with wood fuel, you need to supply 36,000,000
Btu. Refer to the following table for the heat fur-
nished per cord of various kinds of wood. Most of
these average about 20,000,000 Btu per cord, so you
must have 1.8 cords on hand. A cord of wood is a
stack 4 feet high and 8 feet long. If you are fortunate
enough to have a lot of scrap wood available or can
cut your own, this example will pay. If, however, you
have to pay to have fuel wood delivered, it will
probably be too expensive.

It is fortunate that the burning of most kinds of
dry wood produces no harmful exhaust. Of course,
the hotter the combustion area is kept, the more
complete the burning will be. Unlike coal or oil fuels,
wood produces no sulfur in the exhaust; however,
there will be ashes. On the basis of weight, wood
fires leave a relatively small amount of residue.

If you live on a city lot, the best thing to do is to
spread the ashes on a garden spot or flower bed as
they are a source of fertilization, and they can be
returned to the recycling process. You can bury
ashes harmlessly in a yard by digging successive
holes and resodding over them. By a system of
rotation all ashes from a home can be buried
continuously without damaging a yard. Or, you
could pack them for a farmer to pick up, or you
could deliver them to another, larger garden spot. In
some instances, the ashes may be used by com-
mercial factories to make soap.

<table>
<thead>
<tr>
<th>Heat obtained per cord of various species of wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Btu per Cord</td>
</tr>
<tr>
<td>Green</td>
</tr>
<tr>
<td>Ash</td>
</tr>
<tr>
<td>Beech</td>
</tr>
<tr>
<td>Birch</td>
</tr>
<tr>
<td>Douglas Fir</td>
</tr>
<tr>
<td>Elm</td>
</tr>
<tr>
<td>Hickory</td>
</tr>
<tr>
<td>Maple</td>
</tr>
<tr>
<td>Oak</td>
</tr>
<tr>
<td>Pine (Southern Yellow)</td>
</tr>
</tbody>
</table>

Questions

To stimulate thought and greater understanding, answer these questions with the best word(s) to make a
true statement. Refer to the material when necessary.

1. How much sun energy per square meter comes to the United States each day?

2. What is photosynthesis?

3. How much of the original sun energy acts in the photosynthesis process of green plants?

4. Is wood any kin to Kentucky bluegrass, corn, cauliflower or roses?

5. Is firewood, cut to fit a fireplace, any kin to coal?
6. Give two reasons why plants are inefficient converters of solar energy.

7. Name two vital things that the photosynthesis process does for us today and has done in the past.

8. Is the use of wood confined to producing energy in the form of heat for homes?

9. What are two good reasons for utilizing bio-fuels as one source of energy?

10. Why is energy consumed when humans eat plants rather than animal tissue? (Think through the total system before answering.)

11. Can wood and other forms of bio-fuels be economically used to heat homes?

12. What precautions must be taken in locating and installing a wood fire chimney?

13. What can be done to chimney systems to make them produce more heat?

14. What can be easily done to a Franklin-type wood burner to make it produce heat more efficiently?

15. Which steps, if any, in the food chain offer the greatest possibilities for improved efficiencies?

---

**Answers**

1. 200 watts  
2. putting together with light  
3. 1/10 of 1 percent  
4. yes (They are all living plants or biomass.)  
5. yes (Both are biomass.)  
6. intermittence of sun and the complex chemical changes for storage  
7. stores energy in plants, furnishes oxygen  
8. No. It can generate electricity. (Through fermentation it also could be made into methyl alcohol.)  
9. renewable and relatively pollution free  
10. It saves the extra energy needed in other steps.  
11. If the firewood is purchased it is not economical.  
12. be sure it will draw or function without smoking inside  
13. doughnuts, zigzags or large barrels installed to radiate heat  
14. close doors and open bottom vents  
15. Humans could eat cereal grains directly and omit animal products.

Printed with funds from the Kentucky Cooperative Extension Service in cooperation with the Kentucky Department of Energy as a part of the Kentucky Energy Conservation Plan.