

The Potential of Utilizing Chaparral for Energy¹

James R. S. Toland²

ENERGY ASPECTS OF CHAPARRAL

Little did Georgius Agricola of Saxony realize in 1553, when he authored a book on substances in the ground, that the term he invented called "petroleum" would become perhaps the most significant word in any language in the late 20th century (Hoover 1912). Petroleum, then in limited use for heating and lighting, went on to fuel modern civilization in almost every facet of life. Four hundred twenty years later (1973), the world awoke to the realization of the "energy crisis."

Throughout the history of human civilization, mankind has shown a remarkable ability to paint itself into a corner. The resulting crisis, whether it be famine, war, economic peril, or some other circumstance, traditionally brings the world to a crossroad. When it does this, two options usually emerge for the nations of the world. The first option is a strong tendency to become nationalistic or really isolationistic. The second option, more rarely invoked, is to cope with the crisis by motivating the entire population to join forces. Conceivably, the energy crisis could unite the four billion citizens of this planet into recognizing that what is best for the world may also be best for the individual nations.

This may be overly optimistic, given the current political state of the world today. In any case, those nations who must import energy--non members of the Organization for Petroleum Exporting Countries (OPEC)--certainly have a strong motivation to cooperate in research and development of alternative energy sources. It is sobering to realize that of the known petroleum

¹Presented at the Symposium on Dynamics and Management of Mediterranean--Type Ecosystems, June 22-26, 1981, San Diego, Calif.

²Energy Coordinator, Forest Service, U.S. Department of Agriculture.

Abstract: The world energy crisis has caused the United States and other countries to start developing technology for alternative energy systems. Biomass is a versatile fuel with many end uses. Chaparral has the potential to be harvested for energy production from direct utilization, conversion to alternative energy crops such as Jojoba, and by providing energy production sites for techniques such as wind generator farms and solar arrays. This would approach the umbrella objective of reducing the fire-flood sequence thus saving damage costs and energy. Chaparral harvesting techniques need further development, but enough equipment exists to start pilot testing.

reserves, OPEC controls 70 percent, Communist countries control 16 percent, which leaves 14 percent available in the free world (Van Syck 1980). Although each country must organize and attack the energy issue, there is still a strong need to concomitantly work with other countries. Here in the United States, the response to the energy crisis has finally reached the point where one can dare to be optimistic. We are a long way from energy self-sufficiency, but there are some encouraging indicators.

1. A concerted National energy policy is developing in practice--not just on paper.
2. Energy conservation is finally understood by every citizen and stringent efforts to reduce consumption are becoming a way of life. Candidly, only a modest amount of this conservation effort is attributable to altruistic motivation; most is due to one factor--Cost! However, we will cheerfully accept the composite result, which is a well-defined energy conservation effort showing dramatic reductions in energy consumption.
3. We have awakened to the realization that no single entity can solve the problem--not Government, not industry, not labor, not some other country. Rather, we observe a concerted effort evolving to confront the crisis and tackle the solution with less shouting, hair-pulling, and accusations of who caused the problem.

Realistically, any cooperative progress at this stage may be best described as embryonic, but encouraging, nonetheless. I propose to you that this approach is transportable--exportable to the rest of the world. It is true that many countries are seriously involved in the same struggle. The purpose here is merely to remind you of the need for continued and expanded mutual cooperation in energy development. There is a need to look calmly and cooperatively at the achievable rather than dwell upon the dimension

of the catastrophe. The world does not lack alternative energy, only the facilities to utilize what already exists. As the world supply of petroleum and natural gas diminishes and the price escalates, we must turn to other energy sources.

The seriousness of the situation can be graphically illustrated by a quick look at the energy situation in the State of California. The State consumes more energy than any other State and depends upon fossil fuels for 90 percent of total energy needs. Of that total, 54 percent must now be imported from other States and countries (Teller, 1981). It is imperative that the State and the Nation develop alternative energy sources.

The Use of Wood for Energy

In the near term, wood combustion is one of the more promising alternative fuel technologies. The process technology is known, package systems are available, less pollution is generated than for most other alternatives, and the technology for economically harvesting the resource exists or is under development. Wood can be chipped, densified into pellets and briquets to improve its fuel qualities, distilled into alcohol, gasified, pyrolyzed to produce oil and charcoal, and converted to chemicals and plastics to replace petroleum-based products.

The Forest Service has outlined a national program for achieving a goal of 6.4 quads³ of energy from woody biomass by 1990. There are relatively large quantities of unutilized wood that could be used for energy. This includes logging residues, thinnings, wood manufacturing residues, urban wood waste, and trees and brush that cannot now be economically manufactured into wood products. The Forest Service has estimated that over 25 million tons of this material could be made available on an annual basis in California. Economics currently limit the use of much of this material. However, with increasing petroleum prices and better application of research and development efforts, more is being used for energy each year.

World petroleum prices have leveled off during the last few months and this has given rise to a proliferation of optimistic forecasts. The most reliable look at the future is given in the Global 2000 Report. Very briefly, the projection for energy is spiraling costs and decreased supply.

Achievement of the 6.4 quad goal for woody biomass will have a profound effect on the economy, primarily in rural areas. It will mean at

³quad = 10¹⁵ Btu (British thermal unit). This is approximately equivalent to the energy content of one-half million barrels of oil per day for one year.

least 300,000 new jobs, \$9 billion annually in wood industry receipts, and an equal amount of business for supporting industry. The Forest Service expects an additional \$60 million in stumpage receipts plus a savings of \$75 million annually in timber management costs. The equivalent of 760 million barrels of oil will be displaced annually by wood energy. The proportionate effect in California would also be significant (U.S. Dept. of Agric., Forest Service 1980).

Chaparral has the potential to play an important role in biomass utilization for alternate energy development. The magnitude of this resource is significant. There are approximately 11 million acres (4,500,000 ha) of this vegetative type of which 1.5 million acres (607,000 ha) are located in San Diego County (Bolsinger 1980). In our relentless pursuit of the hallowed Btu, chaparral deserves special attention.

Until recently, management of chaparral, particularly in Southern California, has been one of fire exclusion. This has involved a major commitment of workforce and funds by fire protection agencies directed toward prevention and, inevitably, to fire suppression. The approach seemed valid: prevent the chaparral from burning and thereby preserve the watershed and the downstream values. The result has been, rather consistently, the well-known fire--flood sequence. Denuded, the steep slopes lose most of their water and soil retaining ability. When the rainy season arrives, runoff is greatly increased, carrying with it topsoil and even rocks. This often results in heavy downstream damage particularly where the drainages meet the urban zone.

During the last few years, a new concept has been evolving--that of vegetation management. This is defined as actually managing the vegetation with objectives that encompass multiple use. The technology is evolving and as it does the premise of vegetation management looks better each year. "Multiple use" means different things to different people, but certainly one main purpose of a vegetative management program is reduction of the number and size of disastrous wildfires. Currently vegetation management is heavily skewed to prescribed burning. Although this is an acceptable interim measure, it does waste tremendous amounts of energy. From the energy perspective, it is equivalent to "flaring" natural gas in the oil fields and refineries, which was formerly the norm.

To illustrate the energy potential of chaparral, a value of 8,6000 Btu per pound is used.⁴ Chaparral dry weight loading of 10 tons to 50 tons per acre (22,477 kg/ha to 112,038 kg/ha) are quite common. Energy values, therefore, range

⁴Personal Communication from Jay Shelton, Wood Energy Research, 1981.

from 172 million Btu per acre to 602 million Btu per acre (426 million Btu/ha to 2,124 million Btu/ha).

A major thrust of vegetation management could be energy production by several approaches, including direct utilization of the existing chaparral biomass, type conversion to alternative vegetation which produces a greater energy return, and by designating special areas for energy production utilizing such devices as windmill farms (Wind Energy Conversion Systems) or photovoltaic arrays. Any of these approaches would have many payoffs, including reduction of conflagrations.

A Vegetative Classification and Inventory System

Before land managers can really begin scientific management of chaparral, there must exist a commonly accepted classification and inventory system. We do have an energy shortage, but we certainly do not have a shortage of classification systems. A search of the literature shows an impressive number of such systems, each based upon different criteria. There is tremendous variation in data, even in the basic factor of total area of chaparral. The most significant breakthrough needed in chaparral management today is an agreement by land protection and management agencies to adopt one classification system and one biomass inventory system. The California Department of Forestry and the U.S. Forest Service are nearing agreement to standardize using the "CALVEG" vegetative classification system. Accomplishing this would be a very worthwhile step. Nationally, a Federal inventory group based at the Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., has developed a National vegetative classification system. The CALVEG system is designed to fit within this hierarchical scheme, and this is important.

The Honey Lake Project, discussed later in this paper, has resulted in the development of an excellent biomass inventory system. Computer-based, this system provides a standardized inventory system, currently being used on 15 million acres (6,072,875 ha) of forest land in Northern California. It would be an ideal system for State-wide application. To do this would require agreement of principal land management and protection agencies and the assistance of research in developing accurate coefficients to the degree required. This system is up and running, and would be a highly cost-effective method to implement State-wide.

Chaparral Assessment

Data supplied by the above systems would make possible a complete assessment of chaparral lands integrating all significant information. This, for the first time, would provide a data base needed by chaparral planners and decisionmakers.

It can only be accomplished by agreement among land management agencies and the strong support of research.

Alternative Energy Crops

After chaparral on adaptable areas of suitable geomorphology is cleared either by wildfire or harvest, the site would be treated to control brush regrowth. Plantation location, size, and extent of appropriately prescribed energy plants could then be established.

A substantial amount of research and development has been done with some of these energy plants. The plants mentioned here are especially suited for arid or semiarid growing conditions. Collectively, these plants produce a remarkable variety of products including cosmetics, high grade lubrication oils, waxes, rubber, and other chemical feedstock.

Jojoba (Simmondsia chinensis) appears to be the most attractive of these plants. The Office of Arid Lands Studies, University of Arizona, provides leadership and coordination for research and development. Several other universities, particularly the University of California at Riverside, private companies and associations are also actively involved in research, development, and pilot testing of this plant. Jojoba seeds contain 50 percent by weight high grade lubrication oil quite similar to sperm whale oil. Results from a 5-year-old plantation show yields of up to 357 pounds per acre (400 kg/ha) (Yermanos 1979).

Guayule (Parthenium argentatum) produces a different form of energy--rubber. Emergence of this plant as a source of rubber is not new. During World War II, faced with uncertain supplies of this essential commodity, the U.S. Government established the Emergency Rubber Project and planted 30,875 acres (12,500 ha) in California and the Southwest. Interestingly, this organization was largely staffed with personnel from the U.S. Forest Service. When the war ended, so did the project.

In 1976, Mexico launched a research and development program and has an operating pilot processing plant. In 1978, the U.S. Congress passed the Native Latex Commercialization Act authorizing a renewed research, development, and demonstration project for guayule.

Other plants with apparent energy potential include:

1. Buffalo Gourd (Cucurbita spp.)
2. Gopher Plant (Euphorbia lathyris)
3. Meadowfoam (Limnanthes spp.)
4. South American Mesquite (Prosopis chilensis)

Energy farming could also include tree farm crops. Several species of eucalyptus (Eucalyptus spp.), have shown potential for high growth rates with short rotation periods.

Biomass is a very versatile fuel. The major categories include the following:

1. direct combustion
2. gasification
3. pyrolysis
4. chemical production feedstock
5. alcohol production feedstock
6. vegetative type conversion to energy crops.

Each of the above are broad categories and have a number of distinct process variations.

Fuel Processing

Trees and larger brush stems have been used for fuelwood in the past and could form a part of an integrated energy development program. The remainder of the plant with or without the larger component must be chipped, hogged, or densified to facilitate economic transportation. Many types of chippers or hogs already exist which can be ordered off the shelf. Examples include the Fling Demolisher and the Morbark chipper. Some additional development is required to produce an efficient hopper and infeed mechanism to accommodate shrubs instead of logs or slash. For many direct combustion devices, the fuel is now suitable for use. An additional step of reducing the fuel moisture content could improve efficiency and make the fuel suitable for many other types of burners. Densification is a further refinement of chipping or hogging with the added step of applying pressure to produce pellets or briquets.

The California Department of Forestry is the proponent of a contract to produce a prototype mobile densifier. The results of pilot tests with that device should be carefully analyzed. Pressure application devices can also produce products including "Presto Logs" or various sized wafers, flakes, or pellets. The Woodex pelletizer produces a fuel now in wide use. Agri-Fuel is a recent development of Combustion Equipment Associates. This product is a dry, free-flowing powder with a low-ash and low sulfur content, and has a heating value of approximately 8,000 Btu per pound (17,637 Btu/kg). It is suitable for use in many types of furnaces. Obvious advantages include ease of transportation, storage, and handling. The processed fuel or feedstock is also suitable for chemical extraction, alcohol or synfuel production.

Direct Combustion

Residential use of fuelwood for heating and cooking extends from the caveman to modern times. The current resurgence in popularity could not have been predicted just a few years ago. Some of the newly developed fuels, such as briquets or pellets, are suitable for use in existing burning devices without modification. For large-scale use, there is a wide range of commercially available boilers and furnaces with all appurtenances for a complete plant installation. Once a decision is reached on the type of fuel to be used, a complete system can be easily designed for the specific facility.

The proposed Honey Lake Project in Lassen County, California, is an example of an innovative approach to energy production. The project is a hybrid geothermal-wood residue electric power generating facility with a projected output of 50 megawatts.⁵ The process involves using geothermal fluid in the temperature range of 240°F to 350°F (116°C to 177°C) to provide heat for three purposes: (1) to preheat the boiler feedwater; (2) to preheat the furnace combustion air; and (3) to reduce the moisture content of the biomass fuel. As planned, the facility would require 1,000 dry tons (907,200 kg) of biomass per day, which is considered entirely realistic. Involved in funding the feasibility studies are GeoProducts Corp.; Department of Water Resources, State of California; U.S. Department of Energy; and the Forest Service.

An example of innovative technology for producing energy is a steam motor called the Gordon-Torquer, currently being tested. This motor incorporates a new method of utilizing steam with a low engine weight to horsepower ratio and appears to have tremendous potential. It is suitable for direct use with geothermal steam or steam generated by any source.

Gasification

This is an old technology which has been updated with many improvements. Off-the-shelf equipment is available to produce low and medium Btu gas. Medium Btu gas can be compressed, and later reconstituted into a variety of petroleum products. Direct use to operate internal combustion engines or to fuel boilers is a common application.

A gasification unit has been recently installed for a hospital in Rome, Georgia, to provide a complete heating and cooling system, replacing the natural gas and oil fired system used previously. The new unit consumes three tons (2,777 kg) per hour of wood chips which have a moisture content

⁵1 megawatt = 1,000,000 watts.

of approximately 50 percent. The resulting low Btu gas (150 Btu/ft³) (530 Btu/ds) provides 19,000 pounds (8,618 kg) of steam per hour. Capital cost will be amortized in two years.

During the 1930's, Nazi Germany made heavy investments in the development of wood burning gasification systems for vehicles. This was, of course, motivated by a planned future major war which would limit available petroleum. The Germans brought the technology to a point of complete feasibility. During the World War II, this technology was used extensively throughout Germany and German-occupied countries mostly for civilian vehicles. As petroleum once again became available after the end of the war, gasifiers were quickly replaced and the technology was relegated to history--or so it was thought. Since 1973, renewed interest has brought this system out of retirement, updated it with modern technology and this system could be marketed on short notice (Skou and Papworth 1974). Who knows, in the future, a person may drive into a fuel station and order 10 kilos of wood pellets--perhaps chamise (*Adenostoma fasciculatum*) for short, fast freeway trips, and oak (*Quercus* spp.) for longer trips.

Pyrolysis

Pyrolysis is a process in which an organic material is heated to high temperatures and broken down in the absence of oxygen. The result is that 80 percent of the energy value of the biomass is converted to oil, gas, and char. The relative yields are determined by the temperature. The oil fraction equates approximately to number 6 fuel oil, although the heating value is about 30 percent less, or 12,800 Btu/lb (28,211 Btu/kg). The gas so produced can be utilized to operate the pyrolytic converter. One ton (907 kg) of dry feedstock can produce up to two barrels of oil, 200 to 400 pounds (91 kg to 181 kg) of char, plus a quantity of combustible gas. The oil-char mix can be used (with some adjustment) in conventional oil-fired boilers. The char can be separated and aggregated for use as charcoal. Pyrolysis to produce charcoal only is also a feasible alternative. The State of California Solid Waste Management Board has recently completed and has been testing a mobile pyrolytic converter. Data from pilot testing is not yet available. Other versions of converters are successfully operating in various parts of the country.

Chemical/Alcohol Feedstock

Biomass utilized as a feedstock for chemical and alcohol production show much promise. New, more efficient processes are being developed regularly.

Magnetohydrodynamics (MHD)

This is a process to generate electricity that has the potential for greater efficiency than any other method. The technology is in the advanced research and development stage, but results from subscale tests look promising. Basically, this process involves pumping a gas at high velocity through a tube surrounded by a powerful magnetic field. Electrodes protruding into the gas stream cause an electrical current to flow. Experimental design utilizes coal as a source of the necessary gas. Conceivably, biomass could be used and offers the advantage of much lower emissions of SO_x and NO_x. Highly efficient electrical power generation facilities fueled by biomass with low emission rates would be welcome additions to Southern California, in particular.

Biomass Combustion Emissions

Emissions from large scale wood fueled devices are primarily particulates, consisting mainly of ash and unburned char. Emissions of CO, SO_x and NO_x are sufficiently low that no special control is required.

For particulate control, there are six basic types of emission control systems recommended for use: baghouse, wet scrubber, venturi scrubber, multiple cyclone, electrostatic dry scrubber, and electrostatic precipitator. Each type can be used and, of course, each has advantages and disadvantages. For large-scale devices, the most cost-effective type is the electrostatic precipitator.

Environmental Consideration

Harvesting chaparral for energy will require a thorough Environmental Analysis. Careful consideration must be given to archaeology, rare and endangered flora and fauna, soil erodibility and productivity, nutrient depletion, riparian/pseudo-riparian zones, clear-cut block size, visual impacts, coordination with all landowners and public involvement. Data derived during the comprehensive assessment mentioned earlier would be invaluable.

The Laguna-Morena Demonstration Area located in San Diego County, represents a monumental step in coordinated research and development on chaparral management. It has pulled together the most knowledgeable people to develop vastly improved systems for integrated chaparral management. Harvesting for energy has been considered as an alternative and this project offers the most logical springboard for active demonstration of chaparral harvesting and energy farming.

Harvesting Methods

The motivation for harvesting chaparral to date has been mainly to clear fuel breaks and for type conversion to grass. Since this presented a limited market, the incentive has been lacking for the development of mechanized equipment specifically designed for chaparral. The proposed new objective of chaparral harvesting for energy is economic removal of a maximum volume of surface vegetation with appropriate environmental safeguards. Vegetation may be either cut and piled for later removal, chipped, or densified and removed from the site in one operation. Stumps and root systems must be left intact to encourage sprouting.

Conventional Methods

Clearing by hand has included the use of hand tools, gasoline-powered chain saws, and circular wand saws. The work can be done very selectively and on any type of terrain. However, since this is a labor-intensive method, production is slow and per-unit cost is high.

Mechanized equipment includes tractors of various sizes using either straight bulldozer blades or brush rakes. Although this process effectively removes and piles the brush and production rates are good, two serious disadvantages limit extensive use:

1. Excessive soil disturbance with resulting increased erosion potential.
2. Removal of many root crowns and root systems which restricts resprouting.

Other ground-operated methods such as chaining and mulching are considered inappropriate for energy harvesting because of their many disadvantages such as excessive soil disturbance and mixing soil with the biomass.

The Optimum Harvesting System

Terrain dictates two distinct systems for large-scale harvesting operation.

1. For slopes up to 30 percent, an all-terrain vehicle is needed which cuts, shreds, and self-loads an economic payload free of soil and rock. Equipment must be able to avoid rocks, small groves of vegetation, and even individual specimen plants.
2. A system for harvesting steeper slopes.

Unfortunately, such systems are not yet stocked by equipment dealers. Some vehicular harvesters do exist which at least approach the optimum. If a market for such equipment existed, it is probable that development would rapidly follow. The biomass

harvester developed by Georgia Pacific Corporation does perform all the above operations, but current design limits its use to flat land or gentle slopes at the most.

The Shar Twenty manufactured by the Shar Corporation does an impressive job of cutting and shredding brush, but retrieving the debris is not yet perfected. This general type of equipment currently offers the greatest potential.

The ultimate system for steep terrain proposed by several and set forth in detail by Miles and Moini (1980) borrows from the high lead or skyline log yarding system used in many parts of the Western United States.

Such a system could be much lighter in weight and more portable. A ground-operated feller-buncher would cut and stack or windrow the brush. The skyline equipped with tongs would then pick up the material and transport it to a road where further processing would take place. A mobile clipper would reduce the bulk and load it directly onto a truck or storage bins. A densifier could be used on site to produce pellets. Another alternative is to bale the brush much like hay is baled. Transportation could be by truck or large-capacity helicopter. The possibility exists to utilize the biomass on site in a mobile pyrolytic converter. Another "ultimate" system is a harvester similar to the Shar Thirty Machine which would deposit shredded material either in containers or on cargo type nets. When dry, the containers or nets would be picked up by the aircraft called the Helistat and transported to a centrally located concentration yard. The Helistat is under development by the Forest Service in cooperation with the Air Force. Four helicopters are attached to a dirigible with a theoretical payload of 24 tons (21,800 kg).

SUMMARY AND CONCLUSION

1. There is a compelling need to reduce the fire/flood sequence which has historically prevailed on chaparral lands. Managing chaparral lands for energy would be an effective solution to this problem while providing an energy output urgently needed by this country.
2. Biomass is a proven feedstock for a wide variety of energy producing processes.
3. Harvesting chaparral for energy utilization should be an important consideration in chaparral vegetation management.
4. There is an urgent need for land management agencies to reach agreement on using one chaparral vegetative classification and inventory system with complimentary subsystems. There is a significant role in this for research.

5. A complete assessment of chaparral and chaparral lands is needed using data developed in the previous conclusion.
6. An aggressive equipment development program is needed and methods should be pursued to fund this effort. The annual cost of fire and flood damage is ample justification. A joint project involving Federal and State agencies and private companies is suggested.
7. A concerted Research and Development Program using state-of-the-art equipment and techniques should be implemented now.
8. There is a need for an accelerated research program because there are still more questions and guesses about chaparral than there are factual, scientific answers.

LITERATURE CITED

- Anonymous. A national program for forestry; Washington, D.C.: Forest Service, U.S. Dep. Agri.: 1980. Misc. Publ. 1394.
- Bolsinger, Charles L. California forests: trends problems and opportunities. Portland, Ore.: Pacific Northwest Forest and Range Exp. Stn., Forest Service, U.S. Dep. Agri.: 1980. Res. Bull. PNW-89. 138 p.
- Hajny, George J. Biological utilization of wood for production of chemicals and foodstuffs. Madison, Wisc.: For. Prod. Lab., Forest Service, U.S. Dep. Agri.: 1981 March; Res. Paper FPL-385. 65 p.
- Hoover, Herbert. Translation of De Re Metallica. 1912.
- Howard, James O. Wood for energy in the Pacific Northwest: an overview. Portland, Ore.: Pacific Northwest Forest and Range Exp. Stn., Forest Service, U.S. Dep. Agri.: 1979; Genl. Tech. Rep. PNW-94. 28 p.
- Jaasma, Dennis R.; Kurstedt, Harold A. The contribution of wood combustion to national pollutant emissions. Blacksburg, Virg.: Virg. Polytechnic Institute and State Univ. 16 p.
- Johnson, Jack D.; Hinman, C. Wiley. Oils and rubber from arid land plants. Science 208:460-463. 1980 May.
- Miles, J.A.; Moini, S. An approach to harvesting chaparral for energy. Proceedings of the American Society of Agricultural Engineers; 1980 March 18-20; St. Joseph, Mich.: Hilo, Hawaii; American Society of Agricultural Engineers. 11 p.
- Shirley, A. Ray. Wood energy in Georgia. Atlanta, Ga.: Georgia Forestry Commission; 1980 October. 14 p.
- Skou, Miels A.; Papworth, Mark L. The Pegasus Unit. Olympia, Wash.: Pegasus Publishers Inc.; 1974. 133 p.
- Teller, Edward. Speech to the Commonwealth Club, San Francisco, Calif. 1981 January.
- Yermanos, Demetrius M. Jojoba--a crop whose time has come. Berkeley, Calif.: Div. of Agricultural Sciences, Univ. of Calif.; Calif. Agri. 1979 August. 11 p.