Wood as an Energy Resource

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PREFACE

The events precipitating our current reappraisal of fuels availability include the recognition that the world's resources of oil and natural gas, when pitted against demands for those clean and convenient fuels, are inadequate. Before the end of this century, resources of those fuels will be woefully inadequate. Compounding this problem is the acknowledgment that uranium, the hoped-for fuel of the future, is equally limited in availability. The most recent findings of the National Academy of Sciences paint a particularly bleak portrait of uranium resources and reserves for the coming decades. Given those stark situations, one must ask the question: With what policy should we address future energy supply issues?

The energy supply options include whether to put all of our eggs in a few baskets and watch those baskets intently, to paraphrase Mark Twain, or whether to put the energy eggs in many baskets, to paraphrase the earlier secular proverb. Rephrased, the question reads: Should the economy be electrified to the maximum degree and be fueled by breeder-based nuclear power and coal, or should the economy seek as many diverse sources of energy as possible? If the "few fuels" alternative becomes (or, some would say, remains) policy, then we must be prepared to accept a degree of fuel production centralization and a scale or activity unprecedented in history. If the "many fuels" approach is taken, we must be prepared to evaluate each energy source on the basis of how its contribution can best be made to the economy.

The policy question so stated includes but extends beyond technical and economic boundaries; it involves issues of national security, environmental quality, and above all overall philosophy. It is a question of whether to reject or accept solutions that may be applicable to only one region, area, or industry. It is a question of whether the national solution will dictate economic or geographic sector solutions, or whether economic entities will make individual contributions to the total solution.

The question is not whether to use coal and nuclear power. Coal will assume increasing importance for many years to come; and nuclear power will play an expanding role, limited by resource constraints and possibly the sociopolitical undesirability of breeder reactors. One of the key issues, therefore, is the extent to which alternatives can be employed to lessen the pressures now facing coal and other fuels. To what extent are such alternative fuels as wood desirable?

When evaluating one fuel it is a frequent practice to assert that such a fuel can supply, if not all, certainly a large percentage of U.S. energy needs. This practice is perpetrated regardless of whether the energy source under examination happens to be solar power, nuclear power, coal, or cattle dung. Such a position is pointedly avoided here. It is nonsense to believe the notion that wood in particular, or biomass in general, can displace all or most of the other fuels. An industrial economy of the magnitude that we have, if dependent upon wood as a primary fuel, would approach a state described by that Biblical lament, "Woe is me for I am undone." This does not detract, however, from the fact that wood and the other biomass fuels have a very significant part to play in meeting our energy needs. It is a unique part, as the text shows. Given such a disclaimer, we can then ask the question: What is a proper position, a right role, for wood as an energy source?

Wood as an Energy Resource addressed this energy supply topic, first by adopting the philosophy that all supplementary fuels are desirable and should be developed to the maximum extent. That philosophy is adopted because the coal shortage immediately following World War I (which led to riots and deaths), the current petroleum and natural gas shortages causing economic stagnation, and numerous other specific incidents have shown the intellectual and societal bankruptcy of any "few fuels" option, nonrenewable or renewable. The history of Babylon, of Crete, of Greece, and down to that of Nazi Germany confirms that overdependence on one or a few fuels is fraught with peril at all times and ultimately ends up in disaster. Deliberately denying the development of any set of fuel resources is an approach totally devoid of practical value. It is within that frame of reference that the specific evaluation of wood proceeds.

There are numerous specific approaches that can be employed in the analysis of wood as an energy resource. The analytical methods include the technical approach, which examines the biological availability of wood plus the combustion and conversion systems available to use such fuel. Techniques available include an economic assessment dealing with costs of harvesting, combusting, and converting wood materials. A third approach, a comparative approach, also exists. It incorporates elements of the first two analytical methods but treats wood and wood-based materials within the context of the larger family of fuels.

This text adopts that technique and, following comparative analysis, uses wood fuels to examine total energy policy. It traces the historical antecedents

of current wood fuel consumption vis-à-vis other fuels, evaluates present use patterns, develops a fuel value analysis of wood, considers the methods best suited for using that fuel, and finally discusses the resources available for increasing the use of the wood energy resource. In all situations it compares wood to coal, oil, and other fuels available.

This organization is somewhat unusual. Traditionally the resource and potential supply issues are dealt with first. Then comes the discussion concerning how to use the fuels in question. The reason for the inversion of topics is this: underlying the text's organization is a time line. The past comes first and is treated as such. The present is the second period discussed. Considerations of fuel value and methods of fuel utilization are issues of the present. The future is, of course, the final period of concern. The potential resource and supply bases are, in the case of wood, more a future concern than a present concern. This organization has the additional advantage of permitting orderly transitions from historical to technical to economic issues.

This discussion of wood fuels, considered so unimportant that federal statistics ignore them, helps place the entire many-fuel option in clearer focus. Through this discussion, roles for other biomass fuels, solar and geothermal energy, hydroelectric power, nuclear power, and by inference the fossil fuels can be posited. The roles put forward here for various fuels offer one man's views of an energy approach with historical, technological, resource, and economic underpinnings.

The research supporting this text included some unique data. *Area Development*, a professional facility planning journal, permitted me to run a questionnaire designed to obtain fuel preference data. It also included questions concerning co-generation. Those results have been included in this presentation. American Fyr-Feeder Engineers provided me access to their files. These new data concerning markets for wood fuel boilers, hence wood fuels, have been included in this book also. Interviews with a host of specialists provided additional insights. These data obtained cover not only wood fuels but also coal, oil, gas, and the entire spectrum of available energy sources.

In developing and presenting a sound role for wood fuel, I relied upon the assistance of many individuals. These were led by Dr. Kyosti V. Sarkanen, who reviewed every word and drawing in the text. His constant comments and suggestions immeasurably aided the research and sharpened the focus of the effort. Several of the formulas and figures employed stemmed directly from his review. Others who helped were Dr. Bernard Blaustein and Dr. Earl T. Hayes, who made significant contributions to the concepts employed. George Voss of American Fyr-Feeder Engineers arranged for the availability of new data from that company's files. Dr. Fred Shafizadeh and James A. Knight provided significant input. William Landers was particularly helpful in reviewing historical data and ideas. Nationiel Guyol lent out-of-print international reports from the 1930s and 1940s, invaluable materials in the overall

assessment. Albert Jaeggin, editor of *Area Development*, provided assistance in numerous ways. Additional help came from William Axtman of the American Boiler Manufacturers' Association, Dr. John Zerbe and Dr. John Grantham of the U.S. Forest Service, and Dr. Larry L. Anderson of the University of Utah. Finally, of great assistance was my wife, Millie, who typed every version of this text including the one printed here. Without these people, *Wood as an Energy Resource* could not have been completed. With their aid, its writing has been a very exciting and enjoyable experience. So on to the question: What is a proper position, a right role, of wood fuels?

CONTENTS

Chapter 1

A HISTORY OF TRENDS ASSOCIATED WITH FUEL WOOD UTILIZATION

I. INTRODUCTION

That wood and other combustible renewable resources were mankind's first inanimate energy sources, preceding even the use of wind and water power, is well documented. That such combustible fuels exhibited more flexibility than early competitors is also well known. However, the reasons why wood gained initial fuel supremacy, the causes for its decline in both the United States and in other countries, and the historical forces that either promote or constrain its present and future utilization in the energy arena merit examination.

Frequently it is postulated that wood is the fuel of civilization, or the raising of mankind above the level of other primates. Coal is considered the fuel of industrialization. Oil and natural gas are the fuels of advanced industrialization and postindustrial (service) economies. The reasons for such periodic transitions from fuel to fuel, and the role of the declining fuel in the new order, must be understood if the future role of wood among the family of fuels is to be discerned.

In order to make such an analysis, this chapter begins by reviewing the use of wood in the Near East and Europe until 1800 AD, the use of wood as a fuel in the development of the U.S. economy, and finally the use of wood throughout the world

during the first 60 years of the twentieth century. Then, historical forces will be determined as those forces influence the present and future use of wood as a fuel.

II. EARLY USE OF FUEL WOOD IN ASIA MINOR AND EUROPE

The control of fire is considered by Kahn and others to be a cornerstone in human development [1,2]. It achieved acceptance in both domestic and commercial applications. By about 5400 BC the smelting of copper and lead with wood and charcoal was being performed. By 3000 BC the alloying of copper and tin into bronze in charcoal-fired furnaces was a well-established metallurgical process [3]. Such furnaces, at first, were natural draft operations. Then slaves were employed to blow air into the reaction vessel through long reeds and later by operating foot powered bellows. The use of wind to improve metals smelting and refining was, in that era, yet unknown [4].

Wood thus became the primary fuel for early civilizations. The island of Cyprus rose to commercial preeminence based upon this fuel, shipping bronze weapons to the Greek and Roman armies [4]. The Greek civilization gained much of its commercial strength from the operation of wood-fueled silver mining and smelting operations. During this period wood did compete, from time to time, with alternatives such as bitumen, which was employed for a time in Babylon [5], or water power as used by the Roman Empire.

Except for the meeting of requirements for mechanical energy during the Middle Ages, wood remained the primary fuel employed. By that time, however, several forces arose that have affected its utilization ever since. During that period wood-fired smelters produced iron, copper, lead, and other metals throughout Europe. Wood was also used in the mining and ore concentration activities of metals production. Wood consumption was high; for example, it required 14 tons of charcoal to smelt one

ton of iron ore [4]. Extensive deforestation resulted from this unbridled consumption in Europe during the fourteenth and fifteenth centuries, causing smelter failures and the design of mobile furnaces [4]. Further, competition for forests and environmental objection to the wood-based metals production caused some southern European states to outlaw mining with its then attendant tree harvesting operations [6].

The experience of England from the end of the Middle Ages until 1800 is particularly instructive in the problems of wood as a fuel, and the transition of industrializing societies away from this energy source. By the end of the Middle Ages, England had a flourishing iron industry in such regions as Weald and the Forest of Dean. But by the 1600s, fuel shortages began to occur. Few woodlots were over 20 acres in size, and in southeastern England there was virtually no fuel wood at all [7]. The number of iron-producing smelters had declined from several hundred to 55, with 26 being distributed between Weald and the Forest of Dean [4]. Trevelyan asserts that this fuel famine caused a decline of English iron production and an international movement of the iron industry to Scandanavia and America, where forests were plentiful. He adds that the scarcity of wood threatened the ability of the island nation to support its increasing population. Many residential dwellings, along with industry, could obtain no fuel at all [8].

These fuel constraints forced England to lead the world in search of new energy sources [9]. Although coal had been mined since the twelfth century, it was the wood shortage that caused that fossil fuel to arise. Abraham Darby learned to produce coke, and substituted it for charcoal successfully in the production of iron in 1709. This event, in Shropshire, England, led to a massive change in that nation's fuel consumption patterns. By 1788, coke-fired blast furnaces outnumbered charcoal-fired vessels by 59 to 26; and by 1809 the ratio was 162 to 11 [10]. It is significant to note, however, that this fuel transition

depended upon the development of a canal transportation network during the reign of King George III. This system of canals tied the nation's economy together and made coal transportation to inland provinces economical [8]. Thus England's pattern of industrialization relied upon the development of coal as a national fuel, and the construction of an efficient national transportation system.

III. WOOD AS A FUEL IN THE UNITED STATES

The pattern of economic and energy development in the United States differs somewhat from that which occurred in England and Europe, but many parallels also exist. Thus, a careful tracing of fuel utilization in this country elucidates many of the forces now extant that either promote or constrain the use of wood as a fuel. To accomplish this analysis, the following time periods are used: the U.S. in 1800, 1800-1850, 1850-1870, 1870-1920, and 1920-1960. Those periods raise significant issues in the use of wood as a fuel: issues that will remain of importance at least for the rest of this century.

A. The United States in 1800

In order to assess the role of wood as a fuel in the U.S. at the birth of this nation, it is essential to describe society at that time. The use of energy then can be seen, and the use of wood as a fuel can be established in that context.

The 1790 census established that the U.S. population, at that time, was 3.93 million, with only 200,000 or about 5% living in urban areas [11]. Only 3% of the labor force gained employment in manufacturing, while 82.6% worked in agriculture [11]. It was, in short, a capital-short and labor-short economy, which substituted land and the products of the land for capital and labor wherever possible [9].