

# **FUELS AND ENERGY FROM RENEWABLE RESOURCES**

Edited by

**David A. Tillman**

**Kyosti V. Sarkanen**

**Larry L. Anderson**

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FROM RENEWABLE  
RESOURCES**

*Academic Press Rapid Manuscript Reproduction*

SYMPOSIUM ON FUELS AND ENERGY  
FROM RENEWABLE RESOURCES

*174th National Meeting of the American  
Chemical Society, Chicago, August, 1977*

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ACADEMIC PRESS

New York San Francisco London 1977  
*A Subsidiary of Harcourt Brace Jovanovich, Publishers*

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**ACADEMIC PRESS, INC.**

**111 Fifth Avenue, New York, New York 10003**

*United Kingdom Edition published by*  
**ACADEMIC PRESS, INC. (LONDON) LTD.**  
24/28 Oval Road, London NW1

**Library of Congress Cataloging in Publication Data**

**Symposium on Fuels and Energy from Renewable Resources, Chicago, 1977.**

**Fuels and energy from renewable resources.**

**Includes index.**

- 1. Renewable energy sources—Congresses.**
- 2. Fuel—Congresses. I. Tillman, David A.**
- II. Sarkanen, K. V., Date III. Anderson, Lary LaVon. IV. American Chemical Society.**
- V. Title**

**TJ163.2.S96 1977**

**621.4'023**

**77-13450**

**ISBN 0-12-691250-5**

**PRINTED IN THE UNITED STATES OF AMERICA**

**80 81 82 9 8 7 6 5 4 3 2**

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## PREFACE

*Fuels and Energy from Renewable Resources*, as both a symposium and a volume, stemmed from the 1976 American Chemical Society Symposium, *Thermal Uses and Properties of Carbohydrates and Lignins* (also published by Academic Press). The discussions held at San Francisco concluded that serious energy planning should begin, that it should not overlook biomass resources such as silvicultural and agricultural residues, and that these resources should be considered for the near and mid term as well as the long term. Renewable resources, particularly residues, can aid the United States in getting to the year 1985 and beyond.

The symposium *Fuels and Energy from Renewable Resources* was held at the 1977 Fall Meeting of the American Chemical Society. It was sponsored by both the Cellulose and Fuel Divisions. It addressed the issues of energy planning, and the incorporation of crop and conifer residues into the development of energy supply.

To set the framework for the discussions, two papers were given at the beginning—one forecasting total U.S. energy needs and the other depicting the present energy contributions of nonfossil organic materials. From there the symposium moved into a detailed discussion of silvicultural materials—the volume potentially available, their fuel value, and methods of utilization. The energy production–conservation system of generating both steam and electricity from pulp and paper mill residues was among the near-term concepts gaining attention. Limitations on wood as an energy source were also discussed. Similarly, the symposium focused on agricultural residues including contributions on collection, combustion, and conversion. Urban waste concluded the areas of concern covered at this meeting.

The symposium, as a whole, was a multidisciplinary effort. In addition to the chemical and chemical engineering questions of fuel value, conversion, and utilization, issues of economics, environmental protection, and institutional impediments were also addressed. The papers presented at the symposium and in this volume reflect a broad diversity of skills brought to bear on this single aspect of the energy situation.

It is useful to note that, while we are rediscovering renewable resources, other countries regularly include them as part of their energy supply system. Sweden, for example, gets 8% of its energy from wood, while Finland gets 15% of its energy from that source and Brazil gets 27% of its energy from forest fuels. The People's Republic of China has 100,000 operational gas

producers, which convert manure and crop residues into methane-rich gas by anaerobic digestion. India has 50,000 such digesters and South Korea has 20,000. Now this country, driven by limited supplies of oil and gas, is moving in this renewable resource direction.

It is also important to observe that renewable resources, while they can play a far more significant role than they do, will always be a supplemental fuel source. Their potential, at least for the near term, appears to be in the eight quadrillion Btu (quad) per year range. The economy as a whole consumes about 75 quads annually, and that rate of consumption is expected to rise in the coming years. Still, eight quads is a lot of energy. It is equivalent to 1.4 billion barrels of oil, which—when imported—currently cost \$18 billion landed in the U.S.

In order to approach that potential, however, we must first define how much energy we really need; how much we are getting at the present time; and what technologies are now available, or will be available shortly, to improve upon the present contribution from renewable resources. To that end this symposium and this volume were established, and this segment of the energy discussion and debate was joined.

The editors would like to acknowledge the cooperation of all contributors in their timely preparation of excellent papers. We would also like to acknowledge the assistance of Mrs. Mildred Tillman, who in addition to assisting the co-chairmen in the preparation and mailing of letters and forms, typed all of the papers for publication.

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Kyosti V. Sarkanen  
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HOW MUCH ENERGY DO WE REALLY NEED<sup>\*</sup>

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I. INTRODUCTION

The question of how much energy does the Nation need has been debated for several years. The President's National Energy Plan issued last April has focused attention on the energy supply and demand situation for the next eight years. However, we need quantitative estimates of requirements for the longer term to guide the energy research and development effort. A rationale called the requirements approach is developed in this paper and offered as a way to establish strategic objectives for that purpose.

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\* The conclusions and opinions expressed in this paper are those of the author and are not to be considered as statements or positions of the U.S. Energy Research and Development Administration.

The requirements approach has not been used in energy planning and budgeting.\* The procedure used most frequently is to identify existing trends in energy supply or demand and then attempt to trace a likely future using a chain-of-events or scenario technique. The forces of the market place and prices figure prominently in the scenario approach. However, one of the difficulties is that in the long run the outcomes are strongly influenced by the unpredictability of prices. Furthermore, because a very large number of variables are involved, a host of alternate futures can be generated. In practice there is usually no logical ground offered to the decision maker for choosing among scenarios; thus bias is apt to condition the selection.

Because the scenario approach has an open end and generates a large number of possible outcomes, it fosters disagreement and uncertainty about strategic objectives. The requirements approach on the other hand has a closed end. It starts by setting the objectives. This converges agreement and aids in the selection of the preferred ways and means to do the job. When objectives have been set, then scenarios can be used properly to test the desirability and feasibility of any proposed course of action designed to achieve those objectives. Circumstances change in the real world. Therefore, ways must be left open, with enough lead time, to change the targets. For that reason policy formulation based on the requirements approach must be coupled with contingency planning.

It is evident from estimates of the situation that all the potential sources of energy, including renewable resources, must be considered as we determine our future requirements. Given credible estimates of total requirements, it is possible using

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\* The concept is not mentioned as a viable alternative in two recent papers, issued by the Congressional Budget Office: (1) Energy Policy Alternatives and (2) Energy Research, Development Demonstration and Commercialization, Washington, D.C., January 1977.

appropriate analytical techniques to disaggregate the total into individual targets for specific fuels, consuming sectors and regions. This paper is limited to estimation of total requirements. The rationale for estimating the total or aggregate national energy requirements is presented in the next section. In the subsequent section the rationale is used to frame quantitative energy target areas. The effect of conservation on the proposed targets is also examined.

## II. THE RATIONALE FOR ESTIMATING ENERGY REQUIREMENTS

The rationale for estimating future energy requirements is based on the obvious proposition that people need and use energy. Fairly good estimates are available regarding the size of the U.S. population for the next 25 to 30 years. For example, the expected number of 16-year-olds (i.e., those young people becoming available for entry into the labor force) can be estimated within known limits to the year 1993. They are already born. Actuarial calculations tell how many will survive. Incidentally, the number of people reaching age 16 will be decreasing at the rate of about 70,000 per year for the next 15 years. This has important implications for the development of the rationale.

The population projections published recently by the Bureau of the Census [1] provide new estimates based on lower fertility rates. The projections are reported in three "Series." The first, Series I, is similar to the one on which several current energy forecasts have been based, but it is now regarded as being much too high. The other two, Series II and III shown in Table I, appear to be more realistic. Because of the lower fertility rates now occurring in the U.S., it seems reasonable to select Series II as an upper boundary and Series III as a lower boundary for estimating the size of the future U.S. population.

#### 4 Charles M. Mottley

The table also shows the net population increase at 5-year intervals. Note that in both series the net increase declines after 1985.

TABLE I. *Population Estimates and Projections*  
(in millions of persons)

Year	Series II		Series III	
	Population	Net increase	Population	Net increase
1975	213.4	-	213.4	-
1980	222.8	9.4	220.4	7.0
1985	234.1	11.3	228.4	8.0
1990	245.1	11.0	235.6	7.2
1995	254.5	9.4	241.2	5.6
2000	262.5	8.0	245.1	3.9
2005	270.4	7.9	247.9	2.8

If the expected size of the future population and the amount of energy each person is expected to consume are known, then it might be a simple matter to compute the total energy requirements. A study of the situation reveals that it is not quite that simple, even though per capita consumption figures are often used for projection purposes.

Available data on gross energy consumed and total population for the 29 years, 1947-1975, are plotted in Fig. 1. The relationships between energy consumed and population was linear from 1947 through 1962, when an abrupt upward change occurred. A linear trend again prevailed to 1975. In the equations fitted to the data, population is expressed in millions and gross energy consumption in Quads ( $\text{Btu} \times 10^{15}$ ). The regression coefficients in the equations define the linear trends. In the first period

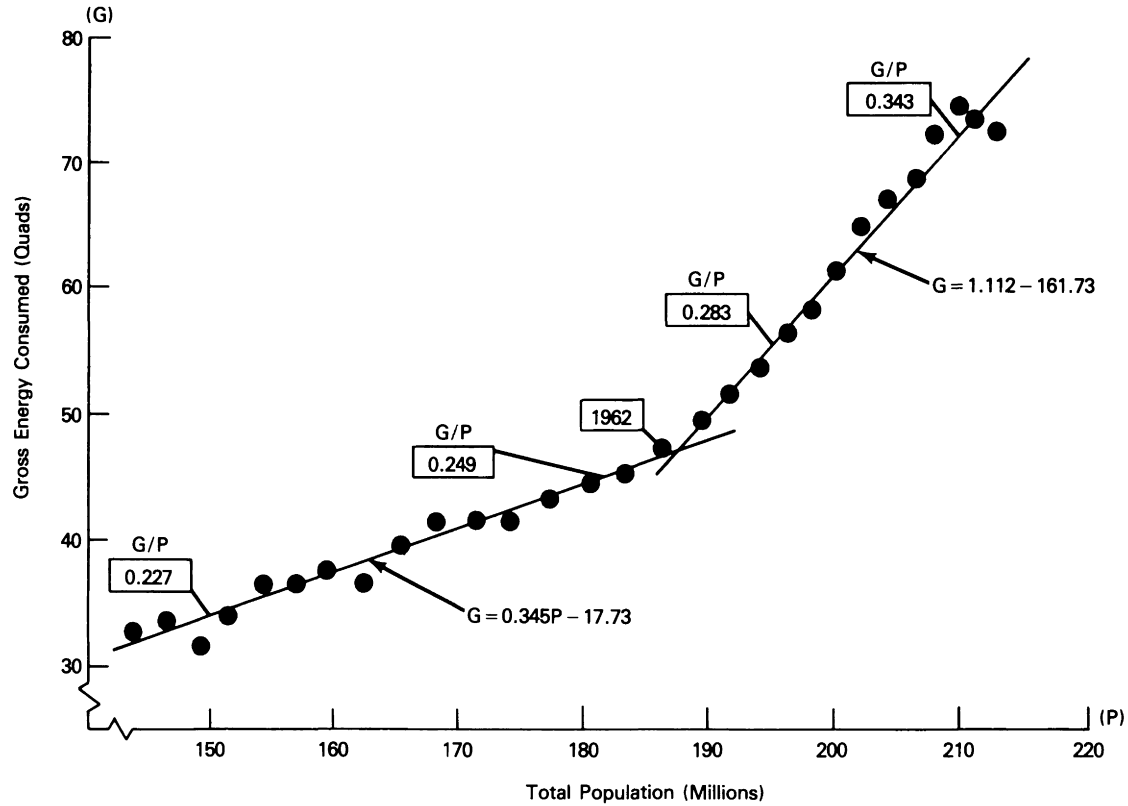


FIGURE 1. Energy consumed by the total population.

(1947 through 1962) each person added to the total population consumed 345 million Btu; after 1962 each additional person consumed 1112 million Btu. There appeared to be a sudden threefold increase beginning in 1962. However, if the ratios for the energy consumed per capita (G/P) are calculated, they would appear to grow as the series progresses: from about 227 million Btu per capita in 1950 to 343 million Btu in 1973. Note also that G/P ratios are much lower than the true rates as indicated by the linear regression coefficients.\*

The question remains: Was there a sudden threefold increase in the rate of energy consumption beginning in 1962? The articulation of this question raises the possibility that the increase might be due to a change in the size of the work force. The growth of civilian employment is shown in Fig. 2. The slope of the two plotted lines represents the net increase in civilian employment. Each year new workers are added and others leave; the net result is an employed work force which has been growing for 30 years. During the period from 1947 through 1962, 637,000 people were added to the number of civilians employed each year. After 1962 the rate of growth was also linear but at the rate of 1,520,000 people per year, or about 2.4 times the original rate.

A more familiar descriptive statistic is the proportion of the total population comprised by the employed force. These data are shown in Fig. 3. Note the declining percentage from 1947 through 1962 and the rise from 1962 to 1974. Incidentally, the percentage of civilians employed in the U.S. has never been higher than 41%.

Because the ratios expressing the number employed as a percentage of the total population present the same mathematical

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\* The apparent growth of the G/P ratios is a mathematical anomaly; the line relating the two variables does not originate at zero and the negative intercept parameter of the equation has not been allowed for in the computation. Under such conditions ratios cannot validly be used for projections or comparative purposes.

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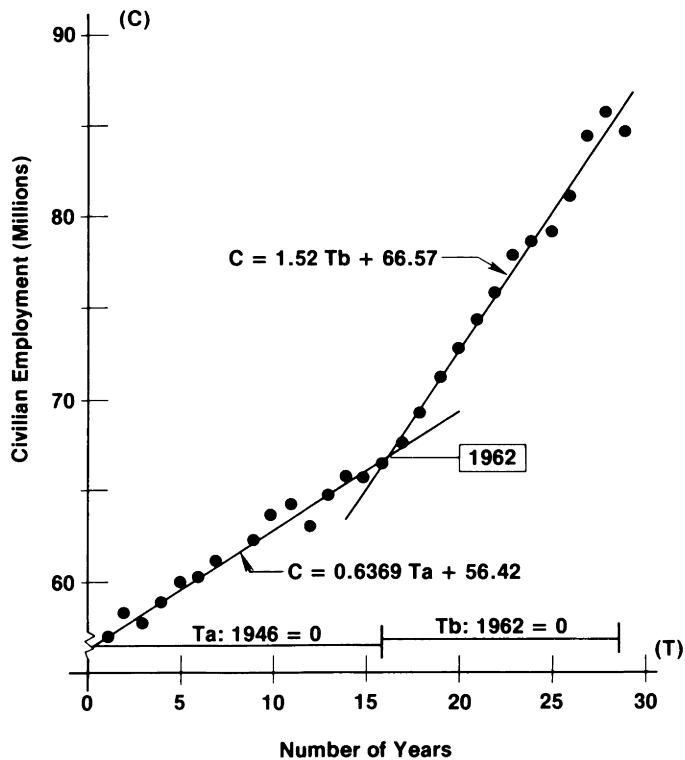


FIGURE 2. The growth of civilian employment.

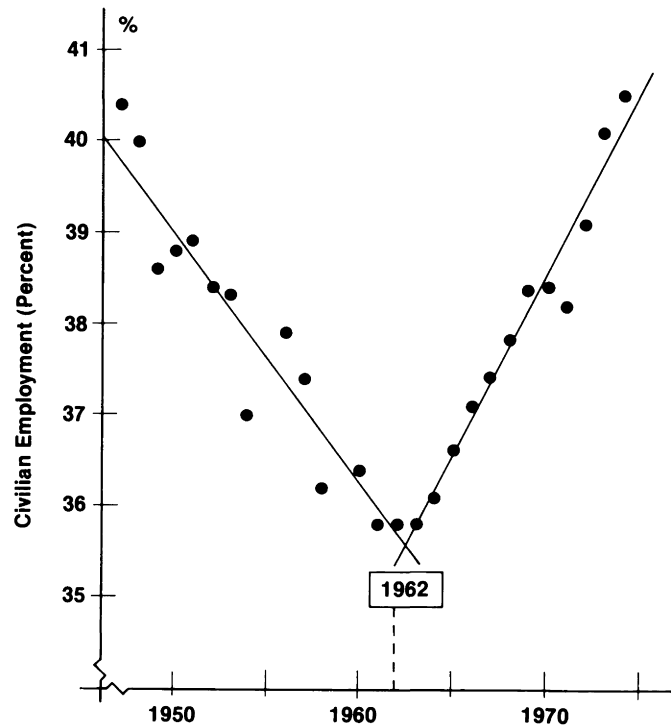


FIGURE 3. Civilian employment as a percentage of the total population.