

**Proceedings of the
Fifth Annual**

**UMR-DNR
CONFERENCE ON ENERGY**



October 10-12, 1978

University of Missouri - Rolla

Missouri Department of Natural Resources

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**UMR-DNR
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**Theme: Energy Involvement:
What We Can Do!**

October 10-12, 1978

Volume 5

**Missouri Department of Natural Resources
Associated Electric Cooperative, Inc.
University of Missouri-Rolla
College of Arts & Sciences
School of Mines and Metallurgy
School of Engineering
Extension Division**

**Edited by
Dr. J. Derald Morgan, Chairman
and Emerson Electric Professor of
Electrical Engineering
University of Missouri-Rolla**

**The Fifth Annual
UMR-DNR
CONFERENCE AND EXPOSITION ON ENERGY**

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American Institute of Industrial Engineers-St. Louis Section
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FOREWARD

This volume is a collection of refereed papers presented at the Fifth Annual UMR-DNR Conference on Energy held at the University of Missouri-Rolla on the dates of October 10 - 12, 1978.

Guided by the President's goal of energy independence by 1980, the UMR-DNR Conference on Energy organized in 1974 with the purpose of providing social scientists, scientists and engineers a means for rapid communication of their most recent research results in the field of energy and to offer solutions to the energy related problems of local government, business, industry and the general public. Since that time, there has been considerable difference of opinion regarding the meaning of energy independence, and even greater differences as to how the goal of independence should be achieved. To some, energy independence is a condition in which the U.S. receives no energy through imports and produces all of its energy domestically. To others, energy independence is a condition in which the U.S. imports some energy to meet its requirements, but only to acceptable levels of political and economic vulnerability.

Concerned citizens throughout our country, aware of the nation's critical dependence on its energy resources, are actively working on solutions to our energy supply and in the

development of new alternatives to traditional energy systems and patterns of energy utilization. At every level -- from trying to lower energy consumption to the development of sophisticated alternatives resources -- concerned researchers are doing what they can to help our nation achieve energy self-reliance and stability.

Papers covering the work of many of the nation's outstanding researchers are contained in this volume. The attention is focused on the future directions to be taken by the scientific, political, social, and institutional forces addressing the energy question and their expected results. The theme, "Energy Involvement: What We Can Do!" was adopted to allow a broad spectrum of responses and recommendations for solutions to the nation's energy problem.

Striving for an exchange of ideas on the energy problem, the UMR-DNR Conference on Energy is sponsored annually by the University of Missouri-Rolla and the State of Missouri's Department of Natural Resources with the cooperation of the professional societies listed on the previous page. Much of the conference support is provided through the company sponsorships. This year's participants in the company sponsorship and registration program are listed on the previous page.

Papers presented at the Conference are of two categories: (1) those that are presented by invitation and (2) those selected from papers submitted in response to an open call for papers. Papers are selected by a committee of experts from the University of Missouri-Rolla and the Missouri Department of Natural Resources in the various fields emphasized in the Conference. Suggestions for papers are always welcome if received by April 15 in the year of the Conference. The meeting is open to all persons interested in energy resources, its extraction, its environmental effects and economics and policies related to energy resources and processes. The Conference provides a forum for social scientists, scientists, and engineers in universities, industry, business or government to meet and exchange ideas between themselves and the general public. Academic sponsorship is intended to provide the freest possible discussion ranging from the most technical detail through the economic questions and

to the social and political aspects of the subject of energy. The sponsors of the Conference and the Director, in particular thank the companies and individuals contributing to the success of the Conference. The help of the Session Chairmen, Co-Chairmen and the Organizing Committee is gratefully acknowledged. A special note of recognition goes to the many authors whose contributions appear in this tome. With their efforts, the success of the Conference was assured, as well as the value of the printed proceedings. Through the continued research efforts of those and other outstanding social scientists, scientists, engineers and public servants, I am confident that our nation will meet the challenges and achieve its goal of energy independence in the 1980's.

J. Derald Morgan
Chairman and Emerson
Electric Professor of
Electrical Engineering,
Conference Director,
UMR-DNR Conference on Energy
University of Missouri-Rolla
Rolla, Missouri



INTRODUCTION

By

James Halligan

UMR-DNR Conference on Energy
October 10-12, 1978

I am here this morning to welcome all of you to the Fifth Annual UMR-DNR Conference and Exposition on Energy and to introduce to you Dr. Joseph M. Marchello, Chancellor of the University of Missouri-Rolla who will be this morning's keynote speaker.

For the past five years, Dr. Marchello has been associated with the University of Maryland as provost in the Division of Mathematical and Physical Sciences and Engineering. This is one of five academic divisions within the University which is located at College Park, Maryland, and has an enrollment in the area of 5,000 students with faculty and staff numbering approximately 600.

Dr. Marchello is a 1955 graduate of the University of Illinois. He received his Ph.D. in chemical engineering from the Carnegie-Mellon University in 1959, and taught at Oklahoma State University from 1959 to 1961. He was a member of the faculty at the University of Maryland from 1961 to 1967, and served as department chairman from 1967 to 1973 at which time he was named provost of the Division of Mathematical and Physical Sciences and Engineering.

Dr. Marchello is a registered professional engineer with special research interests in the areas of chemical engineering and air pollution control. He has served as chair-

man of the Maryland Air Quality Control Advisory Council, a member of the Maryland Advisory Commission on Atomic Energy, chairman of the Maryland Power Plant Siting Committee, and senior operator of the University of Maryland Nuclear Reactor. His professional and honorary society affiliations and assignments include the Air Pollution Control Association, the American Institute of Chemical Engineers, the American Chemical Society, the New York Academy of Science, the American Society for Engineering Education, the American Association for the Advancement of Science, the National Society of Professional Engineers, and the Maryland Society of Professional Engineers.

Dr. Marchello is a native of East Moline, Illinois. His wife, Louis, is a native of Delaware, but actually lived in South Carolina during her youth. The Marchello's have two daughters, Sara Leigh, age 14, and Katherine, 12.

The family enjoys various outdoor activities, such as swimming, boating and fishing; however, the Chancellor says traveling is really their favorite recreational activity.

I now present Dr. Marchello.

KEYNOTE SPEECH

October 10, 1978

Remarks by

J. M. Marchello

Chancellor, University of Missouri-Rolla

NEW ENERGY CONCEPTS - ENGINEERING DEVELOPMENT CHALLENGES

Bringing new energy concepts to commercialization presents formidable engineering challenges requiring considerable amounts of ingenuity and perseverance. Bolstered by the knowledge and experience gained from past accomplishments, engineers can face these challenges with the confidence and assurance that they can continue to create practical applications of science, especially in the pressing energy field.

My first thermodynamics instructor provided me with a lasting impression of the challenging application of energy concepts. At the end of a lecture on the second law and the Carnot cycle for heat engines, he passed out a five-minute quiz consisting of one problem: Prove that Hell is isothermal. Of course, the answer is that, if there were different temperature levels, and in the unlikely chance that someone who understood the second law were sent there, the condemned could build a refrigeration machine and cool off. The problems facing us today are not quite that extreme, but the solution is worth keeping in mind.

One characteristic of the current energy dilemma is the disproportionate rates of use of our energy reserves in relation to their magnitude and location. While this is in part due to political and social decisions, certainly it is also partially a consequence of the failure of engineering developments for the use of coal and other energy sources to keep pace with developments related to use of petroleum and natural gas.

For example, consider the following series of past events in the energy area:

- Rather than developing ways of cleaning up and improving existing coal gasification plants in the 1930's and 1940's, they were phased out in favor of constructing pipelines to bring natural gas to the cities.
- In the 1950's the U.S. Synthetic Fuels Program, based largely on German technology for making oil from coal, was discontinued because there appeared to be an abundance of oil.
- On the other hand, in the 1960's when Middle East crude oil was being delivered to Japan for \$1.50 per barrel, we regulated the import price to nearly twice that amount thereby keeping the U.S. coal industry alive.
- Finally, during the past ten years in response to the Clean Air Act, we converted many electric generating stations to oil because we had not developed ways to burn coal in an environmentally acceptable manner.

This series of events illustrates that a more consistent policy and a longer view of and commitment to technical development would have helped to avoid some of our current problems.

The kind, if not the precise amounts, of our energy resources is known. Also, no new scientific principles are expected to be needed in using these resources. However, new concepts for using our energy resources are continually being proposed. Among these

are potential ways of using energy resources employing plasmas, lasers, solar cells, hydrogen pipelines, combined-cycle electric generating systems, cryogenic superconducting electric transmission lines, and a host of other exciting ideas. Commercializing these concepts raises innumerable practical questions.

The fossil energy industry is of ancient origin and has traditions which sometimes constrain new technical developments. Sophisticated science and engineering have brought to bear on the problems of locating fossil resources and the subsequent recovery of these resources.

However, as suggested in the previous example, relatively little has been done in refining coal, which may be viewed as being analogous to the chemical refining of oil. Even in the case of oil, the major activities have been pointed toward light, high quality feedstocks.

The current price of oil, over four times what it was just five years ago, will support extensive development efforts to make refined products from poor quality feeds. The industry has only recently begun the development of processes for unconventional fuels such as shale oil, tars, heavy crudes, or the conversion of coal to synthetic liquids and gases.

Other fossil fuel energy problems include: What new concepts might be applied in developing in-situ processing of shale oil and coal? How can we improve oil shipping and unloading to reduce spills? Protect against oilwell blowouts? Increase oil and gas recovery from existing fields?

In the environmental protection area there is a general feeling that flue gas SO_2 removal processes represent only interim solutions for use of coal in electric power generation. Combined cycle plants using gaseous or liquid fuels made from coal are

expected to provide substantial energy-conversion efficiency advantages. Given the choice, many utilities will probably select combined-cycle, coal-based systems. But for this choice to be made available to utilities requires both the development of processes for making clean fuels from coal, and the development of combustion turbines capable of operating at temperatures 300°C or more above current levels.

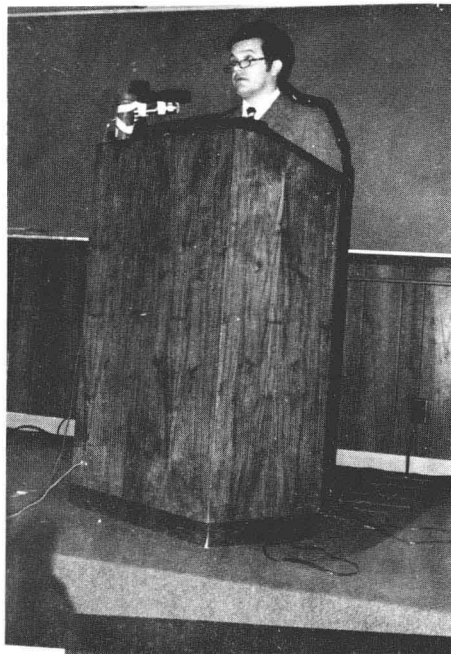
In the solar energy field there are wide-ranging efforts underway for its greater utilization. One of the more difficult problems being investigated is direct conversion. How can we reduce manufacturing costs of solar cells, extend their life, and increase their efficiency?

The growing and processing of biomass is among the few technologies known that provide renewable energy resources. How can the productivity of plants and biomass based fuels be increased? Can ocean areas be used to grow biomass?

Large, highly dispersed, energy resources are available in winds, ocean thermal gradients and waves. Their use requires improved knowledge in meteorology and oceanography, as well as technical developments in marine corrosion and fouling, and development of heat exchangers and heat engines operable at low thermal differentials.

Can engineering developments reduce the potential hazards of nuclear fuel processing and transporting, and reactor operation, while increasing reactor energy conversion efficiency? Engineering materials and containment problems abound in the development of both breeder and fusion reactors. For example, the development of magnetic and inertial containment for nuclear fusion present some of the greatest engineering challenges ever faced.

Geothermal energy holds promise of making a small but significant contribution to our



Keynote Speech
Chancellor J.M. Marchello
University of Missouri-Rolla

October 10, 1978

energy supply. The identification of geothermal resources, improved extraction processes, and estimation of productive capacity require new developments and understanding of geothermal systems, the fluid dynamics of multicomponent - multiphase fluids, and improved materials that can withstand the destructive environments encountered.

The transport of energy in the form of fuel or electricity over long distances in the future may be improved through development of one or more new concepts. For example, in the 1920's the development of seamless, electrically-welded pipe made 1,000 mile oil and gas pipelines possible. Now it is being suggested that as hydrocarbon fuels disappear, energy will be delivered using super conducting electric transmission lines or by pipeline transport of hydrogen produced from water.

Use of superconducting materials would increase electric transmission efficiency. At present these materials lose their superconductivity at temperatures above about 40°K. Can higher temperature materials be developed or, if not, how does one design a cryogenic electric transmission system?

Hydrogen cannot be used in existing pipelines. What developments are necessary for its safe use as an energy transporting medium? Can improved processes for producing hydrogen from water be developed?

Returning to the more immediate situation, one finds many engineering development challenges in the area of energy conservation. Automobiles are being designed for greater fuel economy; heating and air conditioning loads on buildings are being reduced through greater use of insulation and design changes. These and other energy conservation improvements will help provide the time needed for the testing, demonstration and development of the newer concepts for energy use.

The ideas cited above represent but a small sampling of development problems that must be resolved in the arena of engineering practice employing scientific, economic, environmental and social considerations. Certainly there is no shortage of challenging engineering work.

In closing, I would like to share with you another story from my early study of energy. In this instance my Instructor was to give a

CONFERENCE ORGANIZING COMMITTEE

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Dr. Burns E. Hegler, Electrical Engineering, University of Missouri-Rolla - Exposition Director

Dr. William DesVosges, Economics, University of Missouri-Rolla - Assistant Conference Director

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SESSION CHAIRMEN

General Interest Sessions

OPENING MEETING

Introductory Remarks: Dr. J. Derald Morgan, Department Chairman, Emerson Electric Professor of Electrical Engineering and Conference Director

Welcome: Dr. James E. Halligan, Dean of Engineering, University of Missouri-Rolla

Keynote Address: Dr. Joseph M. Marchello, Chancellor, University of Missouri-Rolla

SESSION NO. 1A - SOLAR ENERGY I

Chairman: Dr. Harry J. Sauer, Jr., Department of Mechanical and Aerospace Engineering, University of Missouri-Rolla

Co-Chairman: Dr. Bassem F. Armaly, Department of Mechanical Engineering, University of Missouri-Rolla

SESSION NO. 1B - ECONOMICS OF ENERGY I

Chairman: Dr. Christopher Garbacz, Department of Economics, University of Missouri-Rolla

SESSION NO. 1C - ELECTRICAL ENERGY SYSTEMS & CONTROL

Chairman: Dr. Max D. Anderson, Department of Electrical Engineering, University of Missouri-Rolla

Co-Chairman: Dr. Earl F. Richards, Department of Electrical Engineering, University of Missouri-Rolla

SESSION NO. 1D - WIND ENERGY

Chairman: Dr. Robert B. Oetting, Department of Mechanical and Aerospace Engineering, University of Missouri-Rolla

SESSION NO. 1E - ENERGY EXTENSION PROGRAMS

Chairman: Dr. Burns E. Hegler, Department of Electrical Engineering, University of Missouri-Rolla

Co-Chairman: Dr. J. Byron Nelson, Department of Engineering Management, University of Missouri-Rolla

SESSION NO. 1F - NUCLEAR ENERGY

Chairman: Dr. Albert E. Bolon, Department of Nuclear Engineering, University of Missouri-Rolla

Co-Chairman: Dr. Robert C. Sanders, Department of Nuclear Engineering, University of Missouri-Rolla

LUNCHEON

Speaker: Ms. Alberta C. Slavin, Commissioner of the Missouri Public Service Commission

SESSION NO. 2A - SOLAR ENERGY II

Chairman: Dr. Thomas Van Doren, Department of Electrical Engineering, University of Missouri-Rolla

SESSION NO. 2B - CHEMICAL ENERGY

Chairman: Mr. Jack Howard, St. Louis Regional Commerce and Growth Association

Co-Chairman: Dr. James L. Gaddy, Department of Chemical Engineering, University of Missouri-Rolla

SESSION NO. 2C - ENERGY AND THE ENVIRONMENT I

Chairman: Dr. I. H. Lowsley, Department of Civil Engineering, University of Missouri-Rolla

Co-Chairman: Dr. Bobby G. Wixson, Department of Civil Engineering, University of Missouri-Rolla

SESSION NO. 2D - BUILDING ENERGY USAGE

Chairman: Dr. Wayne C. Turner, Oklahoma State University

Co-Chairman: Dr. Ronald H. Howell, Department of Mechanical Engineering, University of Missouri-Rolla

SESSION NO. 2E - POLITICAL AND SOCIAL IMPLICATIONS OF ENERGY

Chairman: Rev. Clayton Smith, United Ministries in Higher Education, Rolla, Missouri

Co-Chairman: Dr. Adrian H. Daane, Department of Arts and Sciences, University of Missouri-Rolla

SESSION NO. 2F - ECONOMICS OF ENERGY II

Chairman: Dr. Vaman Rao, Department of Humanities and Social Sciences, University of Missouri-Rolla

SESSION NO. 3A - SOLAR ENERGY III

Chairman: Dr. H. Frederick Nelson, Department of Aerospace Engineering, University of Missouri-Rolla

Co-Chairman: Dr. Jack L. Boone, Department of Electrical Engineering, University of Missouri-Rolla

SESSION NO. 3B - MODELING OF SOLAR SYSTEMS

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Co-Chairman: Dr. Ronald H. Howell, Department of Mechanical Engineering, University of Missouri-Rolla

SESSION NO. 3C - ENERGY REGULATION

Chairman: Dr. William DesVousges, Department of Humanities & Social Sciences, University of Missouri-Rolla

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University of Missouri-Rolla

Co-Chairman: Dr. A. Richard Graham, Mechanical Engineering Department, Wichita
State University

SESSION NO. 3E - ENERGY MANAGEMENT

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University of Missouri-Rolla

SESSION NO. 3F - ENERGY FROM BIOMASS

Chairman: Dr. Yildirim Omurtag, Department of Engineering Management,
University of Missouri-Rolla

Co-Chairman: Dr. Virgil J. Flanigan, Department of Mechanical Engineering,
University of Missouri-Rolla

LUNCHEON

Speaker: Dr. Margaret N. Maxey, Professor of Bio-Ethics, University of
Detroit

SESSION NO. 4A - SOLAR ENERGY IV

Chairman: Dr. Jack L. Boone, Department of Electrical Engineering, Univer-
sity of Missouri-Rolla

Co-Chairman: Dr. Harry J. Sauer, Department of Mechanical and Aerospace
Engineering, University of Missouri-Rolla

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of Missouri-Rolla

Co-Chairman: Dr. Bobby G. Wixson, Department of Civil Engineering, University
of Missouri-Rolla

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Chairman: Dr. J. Byron Nelson, Department of Engineering Management, Univer-
sity of Missouri-Rolla

SESSION NO. 4D - FUEL ECONOMY IN TRANSPORTATION

Chairman: Dr. Frank A. Gerig, Jr., Department of Civil Engineering, University
of Missouri-Rolla

SESSION NO. 4E - UTILIZATION OF WOOD PRODUCTS

Co-Chairman: Dr. John Amos, Department of Engineering Management, University of
Missouri-Rolla

Co-Chairman: Dr. Gary K. Patterson, Department of Chemical Engineering, Univer-
sity of Missouri-Rolla

BANQUET

Speaker: Peter Van Nort, Senior Vice President Division & Systems
Operations, Wisconsin Power and Light Company

SESSION NO. 5A - SOLAR ENERGY V

Chairman: Dr. Bassem F. Armaly, Department of Mechanical Engineering, Univer-
sity of Missouri-Rolla

Co-Chairman: Dr. H. Frederick Nelson, Department of Aerospace Engineering,
University of Missouri-Rolla

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Chairman: Dr. Albert E. Bolon, Department of Metallurgical and Nuclear Engineering, University of Missouri-Rolla

SESSION NO. 5C - INDUSTRIAL ENERGY CONSERVATION II

Chairman: Mr. Ron Donovan, Marketing Department, The Gas Service Company, Kansas City, Missouri

Co-Chairman: Dr. J. Byron Nelson, Department of Engineering Management, University of Missouri-Rolla

SESSION NO. 5D - WASTE HEAT UTILIZATION

Chairman: Dr. Ronald H. Howell, Department of Mechanical Engineering, University of Missouri-Rolla

Co-Chairman: Dr. Harry J. Sauer, Jr., Department of Mechanical and Aerospace Engineering, University of Missouri-Rolla

SESSION NO. 5E - ENERGY RESOURCES EXPLORATION AND EXTRACTION

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United Ministries in Higher Education
Rolla, Missouri
Co-Chairman: Dr. Adrian H. Daane
University of Missouri-Rolla

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