

President
President-Elect
Immediate Past President
Past President
Vice President for Finance
Vice President for Communications
Vice President for Publications
Vice President for Business and Government Affairs
Vice President for Academic Affairs
Vice President for Conferences
Student Representative
Appointed Council Member
Appointed Council Member
Appointed Council Member
Appointed Council Member
Appointed Council Member
Appointed Council Member

Ricardo Raineri Bernain
David H. Knapp
Gürkan Kumbaroğlu
Peter R. Hartley
Inga Konstantinavici
Eunbyeong Heo
Anne Neumann
Marisa Leon Almeida
Ying Fan
Ron D. Ripple
Fabian Moisl
Reinhard Haas
Akinbolaji Iwayemi
Machiel Mulder
Vilayat Valiyev
Shree Vikas
Yukari Yamashita

The Energy Journal is a publication of the Energy Economics Education Foundation, Inc., 28790 Chagrin Blvd., Suite 350, Cleveland, OH, 44122-4630, USA, a non-profit organization, in association with the International Association for Energy Economics.

Membership dues for the IAEE include subscriptions to *The Energy Journal* and the *IAEE Energy Forum*. Subscriber and Membership matters should be sent to IAEE, 28790 Chagrin Blvd., Suite 350, Cleveland, OH 44122; phone 216-464-5365, fax 216-464-2737. Non-member subscriptions to *The Energy Journal* are \$475 for institutions, libraries, and individuals. Postage and handling are paid by the publisher. Outside the United States and Canada, non-member subscriptions are \$500.

Articles appearing in *The Energy Journal* are listed in both *Envir. Per. Bibliography* and *The Journal of Economic Literature* and are indexed/abstracted in *ABI/Inform*, *EconLit*, *JEL on CD*, *ISI Journal Citation Reports*, *Web of Science*, *SciSearch*, *Research Alert*, *Ei COMPENDEX*, *Trade and Industry Index*, *PAIS International*, *DOE Energy*, *Energy/Enviroline*, and *Wilson Business Abstracts*, and the following EBSCO databases: *Academic Search Premier* and *Business Source Premier*.

Authorization to photocopy articles appearing in *The Energy Journal* for internal or personal use, or the internal or personal use of specific clients, is granted by IAEE provided that you first register with the Copyright Clearance Center. Please access www.copyright.com or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of uses. *The Energy Journal* is available in reference systems (e.g., microfilm, CD-ROM, full text etc.) produced by the ProQuest Co. (*ProQuest Information & Learning*), the Gale Group (*Info Trac* databases) and the H.W. Wilson Company's Business Periodicals Index. For further information please contact ProQuest Company at 734-761-4700, www.proquestcompany.com, the Gale Group at 248-699-4253, www.galegroup.com, or H.W. Wilson Co., at 718-5888400, www.hwwilson.com, or EBSCOhost.

AUTHORS: Please see back pages for information on the proper style of submissions.

ADVERTISING INFORMATION: For a complete media kit, contact Marketing Department, IAEE Headquarters, 28790 Chagrin Blvd., Ste. 350, Cleveland, OH, 44122-4630. Phone: 216-464-5365, fax: 216-464-2737. E-mail: iaee@iaee.org. Homepage: <http://www.iaee.org>.

The Energy Journal (ISSN 0195-6574 / E-ISSN 1944-9089) is published bimonthly by the Energy Economics Education Foundation, 28790 Chagrin Blvd., Ste 350, Cleveland, OH, 44122 and additional mailing offices. Subscription price \$475, U.S. and Canada; \$500 other countries. POSTMASTER: Send address changes to EEEF, 28790 Chagrin Blvd., Ste 350, Cleveland, OH 44122.

Copyright © 2017 by the International Association for Energy Economics. All rights reserved.

The editors and publisher assume no responsibility for the views expressed by the authors of articles printed in *The Energy Journal*. Printed in the U.S.A.

Editor-in-Chief, Adonis Yatchew
Editors, Lester C. Hunt and James L. Smith
Managing Editor, Geoffrey Pearce
Book Review Editors, Carol Dahl, Maureen Crandall, and Frank Felder

Board of Editors

Adeola F. Adenikinju
University of Ibadan

Lars Bergman
Stockholm School
of Economics

David Broadstock
Hong Kong Polytechnic
University

Young Ho Chang
Nanyang Technical
University, Singapore

Ying Fan
Beihang University

Massimo Filippini
University of Lugano
ETH Zurich CEPE

Kenneth Gillingham
Yale University

Jean-Michel Glachant
European University
Institute, Florence, Italy

Richard Green
Imperial College London

James M. Griffin
Texas A & M University
College Station, Texas

Eunnyeong Heo
Energy, Environmental and
Engineering Economics
Center, Seoul National
University

William W. Hogan
Harvard University
John F. Kennedy School of
Government

Einar Hope
Norwegian School
of Economics and Business
Administration

Mark K. Jaccard
Simon Fraser University
British Columbia, Canada

Paul L. Joskow
President, Alfred P. Sloan
Foundation, New York

Edward Kahn
Analysis Group, Inc.
San Francisco, CA

Valerie Karplus
MIT Tsinghua Energy China

Andreas Loeschel
University of Munster

Karsten Neuhoff
DIW Berlin

André Plourde
Carleton University
Ottawa, Canada

Michael Pollitt
Judge Business School
University of Cambridge

Ricardo Raineri
Pontificia Universidad
Católica de Chile

Adam Rose
University of Southern
California
Los Angeles, CA

Juan Rosellon
CIDE, Mexico

Geoffrey Rothwell
OECD Nuclear Energy
Agency

Margaret F. Slade
UBC, Vancouver School of
Economics

Thomas Sterner
Göteborg University
Sweden

Paul Stevens
Chatham House, UK

**Christian von
Hirschhausen**
Technical University, Berlin

Catherine Waddams
University of East Anglia
United Kingdom

W. David Walls
University of Calgary
Alberta, Canada

John P. Weyant
Stanford University, CA

Franz Wirl
University of Vienna,
Department of Business
Studies, Austria

Catherine Wolfram
Haas School of Business
University of California
Berkeley, CA

Chi-Keung Woo
Department of Asian and
Policy Studies, Education
University of Hong Kong

THE ENERGY JOURNAL

Volume 38, Number 6, 2017

Table of Contents

Papers

Inter-temporal R&D and Capital Investment Portfolios for the Electricity Industry's Low Carbon Future <i>Nidhi R. Santen, Mort D. Webster, David Popp, and Ignacio Pérez-Arriaga</i>	1
Why Consumers Switch Energy Suppliers: The Role of Individual Attitudes <i>Xiaoping He and David Reiner</i>	25
The Effect of Information on TOU Electricity Use: An Irish Residential Study <i>Shirley Pon</i>	55
Fuel Prices and Station Heterogeneity on Retail Gasoline Markets <i>Justus Haucap, Ulrich Heimeshoff, and Manuel Siekmann</i>	81
Remuneration of Flexibility using Operating Reserve Demand Curves: A Case Study of Belgium <i>Anthony Papavasiliou and Yves Smeers</i>	105
The Impact of the Fracking Boom on Arab Oil Producers <i>Lutz Kilian</i>	137
Fossil Fuel Price Shocks and CO ₂ Emissions: The Case of Spain <i>Jorge Blazquez, Jose Maria Martin-Moreno, Rafaela Perez, and Jesus Ruiz</i>	161
Cost, Contractors and Scale: An Empirical Analysis of the California Solar Market <i>Johannes Mauritzen</i>	177
Geospatial, Temporal and Economic Analysis of Alternative Fuel Infrastructure: The Case of Freight and U.S. Natural Gas Markets <i>Yueyue Fan, Allen Lee, Nathan Parker, Daniel Scheitrum, Amy Myers Jaffe, Rosa Dominguez-Faus, and Kenneth Medlock III</i>	199

Book Reviews

<i>Introduction to Energy Analysis</i> , 2nd edition, by Kornelis Blok and Evert Nieuwlaar <i>Chiara Lo Prete</i>	231
<i>Energy Efficiency: Building a Clean, Secure Economy</i> , by James L. Sweeney <i>Carol A. Dahl</i>	232
Index to Volume 38	235

Geoffrey Arnold Pearce

10/19/1959–6/23/2017



Geoffrey Arnold Pearce, the Managing Editor of *The Energy Journal*, passed away unexpectedly on June 23, 2017. Geoff's *electronic persona* had a global reach, but few in our international community of energy economists had the opportunity to meet him in person.

Geoff was a unique person in many ways. A geologist by training, he loved the outdoors. After graduating, Geoff worked for mining exploration companies during much of the 1980s, often spending months away in the bush, far from the comforts of home. In the early 1990s Geoff worked as a reporter for a mining newspaper.

Geoff began work with *The Energy Journal* in 1992 where he was the Associate Editor and, at the time of his passing, the Managing Editor. He was the cornerstone of the operation, processing hundreds of papers and thousands of referee reports, emails and correspondences year after year. Throughout, Geoff was unfailingly professional, personable and above all, caring. It is especially telling that in a quarter of a century with the *Journal*, not a single complaint was received about Geoff; not one, only praise. When one considers that Geoff was frequently the deliverer of unhappy tidings, this simple fact speaks volumes.

Geoff was a skilled clarinetist and an accomplished diver. One of his musical favorites was *Calypso*, a song written by John Denver as a tribute to Jacques Cousteau. The opening verse captures Geoff's essence—his love of nature and the exhilaration of adventure, the challenges of life and service to others, and his unquenchable desire for knowledge and understanding.

“To sail on a dream on a crystal clear ocean
To ride on the crest of a wild raging storm
To work in the service of life and living
In search of the answers to the questions unknown
To be part of the movement and part of the growing
Part of beginning to understand.”

Adonis Yatchew
Editor-in-Chief, *The Energy Journal*

SUBSCRIPTION ORDER FORM

THE ENERGY JOURNAL*Published by International Association for Energy Economics*

OVERVIEW: *The Energy Journal* is published by the International Association for Energy Economics. It is the Association's premier journal and is published four times a year. The journal encompasses a broad spectrum of energy economics topics such as:

- ◆ Alternative Transportation Fuels
- ◆ Hydrocarbon Issues
- ◆ Conservation of Energy
- ◆ International Energy Issues
- ◆ Economic Energy Modeling
- ◆ Issues in Exploration & Production
- ◆ Energy Demands and Usage
- ◆ Markets for Crude Oil
- ◆ Electricity and Coal
- ◆ Natural Gas Topics
- ◆ Energy & Economic Development
- ◆ Energy Management
- ◆ Energy Policy Issues
- ◆ Environmental Issues & Concerns
- ◆ Greenhouse Effect & Change
- ◆ Nuclear Power Topics
- ◆ Petroleum Topics
- ◆ Renewable Energy Issues
- ◆ Theory & Practice of Energy Related Issues
- ◆ Developing World Energy Issues

This professional journal carries a variety of other topics as well. Also included are topics of timely energy interest, research papers and reports, book reviews, government reports on energy policy and prospects and advertisements of interest to readers. This is one publication every learned library should have in its collection.

Please select one of the following:

SINGLE SITE/CAMPUS online license:

Online (Includes current volume plus full online back file access to all volumes and issues while subscription remains active)	\$675.00
Online + Print (Includes current volume online and in print plus full online back file access to all volumes and issues while subscription remains active)	\$925.00 + postage
Postage U.S. and Canada	\$80.00
Postage rest of world	\$100.00

Subscription Length: ☐ 1 Year ☐ 2 Years ☐ 3 Years ☐ 4 Years ☐ 5 Years

Send payment in U.S. funds with a check drawn on a U.S. bank

☐ Make check payable to IAEE in U.S. dollars with checks drawn on a U.S. Bank

☐ Visa or ☐ Mastercard

TOTAL ENCLOSED \$ _____

Card No. _____ Exp Date _____

Signature _____ CVC2 Code _____

SUBSCRIPTION ADDRESS:

Name/Title _____

Company _____

Address _____

City, State, Mail Code _____

Country _____

Send order form along with payment to: International Association for Energy Economics,
28790 Chagrin Blvd., Suite 350, Cleveland, OH 44122, USA

Phone: 216-464-5365 • Fax: 216-464-2737 • Email iaee@iaee.org • Website: www.iaee.org

Submission Guidelines

The Energy Journal publishes original theoretical and empirical papers devoted to the advancement and dissemination of knowledge on energy and related topics. Content and editorial board composition are international in scope. Although most articles emphasize the economic aspects of their subjects, coverage is interdisciplinary. *The Energy Journal* quarterly issues include:

- Major, refereed articles that deal with theoretical or applied problems of continuing interest in energy economics and related disciplines.
- Shorter, refereed papers and notes that are topical and that focus on the theory and practice of economics as related to energy and energy policy.
- An 'Energy Perspectives' section which contains refereed papers that review or analyse important current issues from a broader vantage point.
- A 'Book Review' section which examines books and topical government reports (national and international) on energy economics, energy policy and related areas.

Submitting Manuscripts for Refereeing

The Energy Journal uses a single-blind refereeing process in which authors are identified to referees, but not vice versa. Authors, please submit an electronic copy of your paper in pdf format for refereeing, with the authors' names included at <http://www.iaee.org/ejsubmit/submitjournal.aspx>.

Manuscripts submitted for refereeing should be prepared according to the following style rules, which are based on The Chicago Manual of Style. The submission fee for articles submitted to *The Energy Journal* is \$100. (There is no fee if at least one author is an IAEE member.)

Manuscripts should be double-spaced on a page size of 8.5 x 11 inches or the metric equivalent. The first page should contain the article title, author(s) name(s) and complete affiliation(s), title, and complete mailing address of the person to whom all correspondence should be addressed. An abstract of no more than 150 words must be included. Please include keywords below the abstract. Manuscripts may not be longer than 25-35 pages maximum or 9,500 words.

Mathematical expressions should be set in italic type with all equations numbered consecutively on the right hand side of the page. Articles should carry no more than 12 complex equations (defined as multi-lined equations).

Tables should be numbered consecutively. All tables should have concise titles.

Footnotes should be numbered consecutively with superscript Arabic numerals. Footnotes are placed at the bottom of each page.

All figures should be numbered consecutively throughout the text.

Authors submitting a manuscript do so with the understanding that if it is accepted for publication, copyright in the article, including the right to reproduce the article in all forms and media, shall be assigned exclusively to *The Energy Journal*. The *Journal* will not refuse any reasonable request by the author for permission to reproduce any of his or her contributions to the journal.

Submitted papers may undergo electronic web-based analysis to ensure their originality and to identify possible cases of plagiarism. Submission to *The Energy Journal* implies that the authors grant permission that such analyses may be performed.

Style and Format for Accepted Manuscripts

Accepted manuscripts must be submitted in electronic form as either MS Word or LaTeX files. Electronic MS Word files must incorporate all text, tables, equations and graphics. Equations should be in equation editor (or MathType) format. Make sure that they have not inadvertently been converted to a graphic.

For LaTeX submissions, any separate files used in creating the pdf output file must be included, especially graphics files and a bibliography file if it was used to create the list of references. The pdf output of LaTeX files should also be submitted, preferably using the template available on our web site, which will format the article according to our style requirements and allow you to place graphics, tables etc. appropriately. Click here to download the LaTeX template files.

Figures must be submitted as camera-ready copy in a form suitable for reproduction. In addition to the figures placed in the manuscript files, each figure must be provided unembedded as a separate, high-resolution file (at least 300 ppi, and 600 ppi recommended) for typesetting. Acceptable file formats include EPS, TIFF, JPEG, GIF, PNG, BMP, XLS, XLSX, DOC, DOCX, and PDF. The *Journal* does not publish in color. Thus, color figures will be converted to grayscale for the print publication. If such conversion will result in poor distinction between parts of the figure, the author must also submit a separate grayscale version that enhances the distinction.

(continued)

References should be provided using the author-date citation system. Papers should include an alphabetical reference list of all works cited. All works in the reference list must be cited in the text, and citations should be “in-line”, or “static text”. You may also review past issues of *The Energy Journal* to see our style of references. Examples follow:

Style For Book:

Chandler, Alfred (1977). *The Visible Hand*. Cambridge: Belknap Press.

Style For Report:

Federal Trade Commission, Bureau of Economics (1979). *The Economic Structure and Behavior of the Natural Gas Production Industry. Staff Report*.

Style For Journal Article:

Henderson, J.S. (1986). “Price Determination Limits in Relation to the Death Spiral.” *The Energy Journal* 7(3): 150-200.

Executive Summary

In order to improve the accessibility of *Energy Journal* papers, authors are required to submit a short (one to two page) non-technical Executive Summary which contains the following: a) the motivations underlying the research; b) a short account of the research performed; c) the main conclusions; and, d) potential benefits, applications and policy implications of the work. No tables, charts, graphics, equations, etc. are to be included in the Executive Summary.

Authors are encouraged to include the Executive Summary with their initial submission. Otherwise, it must be submitted together with the first revised version of the paper. Failure to provide the extended abstract will result in delays in the review process and potentially delays in publication.

The Executive Summary will be posted on the IAEE website in advance of the official publication date of the issue of *The Energy Journal* that carries the author’s article. The purpose of this new, stand-alone document is to communicate the central ideas contained in the research to the non-technical reader. It is the editors’ belief that this will benefit not only authors, whose work will be more widely recognized, but also the broader policy, industry and governmental communities which are constantly in search of answers to difficult energy-related questions.

Revised Article Resubmission

Revised articles, along with the Executive Summary, should be emailed directly to the Associate Editor at geoffrey.pearce@utoronto.ca.

Page proofs will be sent to the corresponding author for approval before publication.

Data Availability Policy

The Energy Journal is committed to the principle that results in papers that it publishes must be replicable. Once a paper has been accepted, the author(s) must confirm his/her willingness to make data and programs available to other researchers on a request basis. The *Journal* recognizes that in some cases, data and/or programs are proprietary or may have required considerable resources to assemble. If this is the case, the author(s) are required to write a letter to the Editor in charge of the paper to explain the circumstances. In such cases it is expected that the author(s) be willing to share their data/programs on the condition that the researcher will use the materials solely for the purpose of replicating the results.

Additional Notes

The Editors of *The Energy Journal* may submit papers for publication consideration by following the procedures and criteria as approved by the Board of Editors. Please visit <http://www.iaee.org/documents/EJPolicy.pdf> for further information.

Book Reviews

To submit Books for review, please contact Associate Editor Geoff Pearce at geoffrey.pearce@utoronto.ca.

Book Review Editors:

Carol Dahl, Colorado School of Mines.
cadahl@mines.edu

Maureen S. Crandall, National Defense University, crandallm@ndu.edu

Peter J.G. Pearson, Cardiff University,
Pearsonpj@cardiff.ac.uk

Frank Felder, Rutgers University,
ffelder@rci.rutgers.edu