

Science and Technology Policy Institute

State-Level Changes in Energy Intensity and Their National Implications

MARK BERNSTEIN

KATERYNA FONKYCH

SAM LOEB

DAVID LOUGHRAN

Prepared for the
U.S. Department of Energy

RAND

The research described in this report was conducted by RAND's Science and Technology Policy Institute for the U.S. Department of Energy under contract ENG-9812731.

Library of Congress Cataloging-in-Publication Data

State level changes in energy intensity and their national implications / Mark Bernstein ...
[et al.].

p. cm.

ISBN 0-8330-3416-2 (Paperback)

"MR-1616."

1. Energy policy—United States—States. 2. Energy conservation—Government
policy—United States—States. I. Bernstein, Mark, 1956–

HD9502.U52S8146 2003

333.79'16'0973—dc21

2003009703

RAND is a nonprofit institution that helps improve policy and decisionmaking through research and analysis. RAND® is a registered trademark. RAND's publications do not necessarily reflect the opinions or policies of its research sponsors.

© Copyright 2003 RAND

All rights reserved. No part of this book may be reproduced in any form by any electronic or mechanical means (including photocopying, recording, or information storage and retrieval) without permission in writing from RAND.

Published 2003 by RAND

1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

1200 South Hayes Street, Arlington, VA 22202-5050

201 North Craig Street, Suite 202, Pittsburgh, PA 15213

RAND URL: <http://www.rand.org/>

To order RAND documents or to obtain additional information, contact Distribution Services: Telephone: (310) 451-7002; Fax: (310) 451-6915; Email: order@rand.org

Preface

About This Analysis

In May 2001, the Bush administration released its National Energy Policy. Several of the policy's recommendations call for the U.S. Department of Energy (DOE) to explore opportunities and implement programs for further improving U.S. energy intensity (defined as energy consumption per dollar of gross economic output).

At the request of the DOE's Office of Energy Efficiency and Renewable Energy, RAND examined changes in energy intensity across states from 1977 through 1999 as part of a larger effort to identify factors at the state level that have contributed to efficient energy use. This study is intended as a first step in helping the DOE to identify state actions that may have led to reductions in energy intensity over the past two decades.

This report should be useful to policymakers at the national and state level who are interested in better understanding changes in energy intensity and the cause of those changes. Technical appendices are provided in this report for analysts and others who want to delve more deeply into the analytical approach and data used in this study.

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was created in 1976 to provide the president of the United States with timely policy advice and to coordinate the federal investment in science and technology.

About the Science and Technology Policy Institute

Originally created by the U.S. Congress in 1991 as the Critical Technologies Institute and renamed in 1998, the Science and Technology Policy Institute is a federally funded research and development center sponsored by the National Science Foundation and managed by RAND. The Institute's mission is to help improve public policy by conducting objective, independent research and analysis on policy issues that involve science and technology.

To this end, the Institute

- supports the OSTP and other Executive Branch agencies, offices, and councils
- helps science and technology decisionmakers understand the likely consequences of their decisions and choose among alternative policies
- helps to improve understanding in both the public and private sectors of the ways in which science and technology can better serve national objectives.

In carrying out its mission, the Institute consults broadly with representatives from private industry, institutions of higher education, and other nonprofit institutions.

Inquiries regarding the Science and Technology Policy Institute may be directed to:

Helga Rippen, PhD, MD, MPH

Director

Science and Technology Policy Institute

RAND

1200 South Hayes Street

Arlington, VA 22202-5050

Phone: (703) 413-1100 x5574

Web: <http://www.rand.org/scitech/stpi>

Email: stpi@rand.org

Contents

Preface	iii
Figures	vii
Tables	ix
Summary	xi
Acknowledgments	xv
Acronyms	xvii
1. INTRODUCTION	1
Background	1
Study Objectives	2
Study Limitations	3
Future Analysis	4
Organization of This Report	4
2. STATE-LEVEL TRENDS IN ENERGY INTENSITY	7
3. FACTORS AFFECTING ENERGY INTENSITY	13
Factors That May Explain Differences Across the States	13
Factors That May Explain Differences Across the Energy- Consuming Sectors	16
Industrial Sector	16
Commercial Sector	16
Residential Sector	17
Transportation Sector	17
4. MODELING ENERGY INTENSITY	19
5. IMPACT OF FACTORS AND COMMON EFFECTS ON ENERGY INTENSITY	23
Total Energy Consumption	23
Industrial Sector Energy Intensity	25
Commercial Sector Energy Intensity	25
Residential Sector Energy Intensity	28
Transportation Sector Energy Intensity	29
Comparing Results from 1977–1987 and 1988–1999	30
6. APPLYING THE ANALYSIS RESULTS TO EXAMPLES OF ENERGY INTENSITY OUTCOMES	33
Industrial Sector Example	33
Commercial Sector Example	34
Residential Sector Example	35
7. RANKING THE STATES WITH THE GREATEST ENERGY INTENSITY AND RESIDUAL EFFECT REDUCTIONS	37
Energy Intensity Rankings by State Across All Sectors	37

Industrial Sector Rankings	39
Commercial Sector Rankings	42
Residential Sector Rankings	43
Transportation Sector Rankings	45
8. WHAT WOULD HAPPEN TO U.S. ENERGY INTENSITY IF ALL STATES REPLICATED THE TOP-RANKED OR BOTTOM-RANKED STATES?	47
9. CONCLUSIONS AND THOUGHTS FOR FUTURE ANALYSIS	51
Appendix	
A. DATA SOURCES	53
B. REGRESSION ANALYSIS RESULTS	59
C. METHODOLOGY FOR CALCULATING THE WHAT-IFS IN CHAPTER 8	73
D. DETAILED RESULTS OF ENERGY INTENSITY ANALYSIS	79
Bibliography	93

Figures

S.1. Common Effect, Factor Effect, and Residual Energy Intensity for the Five Top-Ranked States in Residual Energy Intensity Reductions, 1988–1999	xiii
2.1. Changes in Each State’s Energy Intensity, 1977–1999	7
2.2. States’ Average Annual Percent Change in Residential Energy Intensity, 1979–1999	8
2.3. Percent Change in Industrial Energy Intensity for Selected States Versus U.S. Average, 1977–1999	9
2.4. Percent Change in Average Energy Price by Energy-Consuming Sector Versus U.S. Average, 1977–1999	10
2.5. Average Weighted Energy Price for the 48 Contiguous States Collectively, 1977–1999	11
6.1. Common Effect, Factor Effect, and Residual Energy Intensity for Nevada, Nebraska, and Montana, 1988–1999	35
7.1. Common Effect, Factor Effect, and Residual Energy Intensity for the Top-Ranked States in Residual Energy Intensity Reductions, 1988–1999	38
7.2. Factor Effect and Residual Energy Intensity for the States with the Largest Industrial Sector Energy Intensity Reductions in 1988–1999	41
7.3. Common Effect, Factor Effect, and Residual Energy Intensity for the States with the Largest Commercial Sector Energy Intensity Reductions in 1988–1999	43
7.4. Factor Effect and Residual Energy Intensity for the States with the Largest Residential Sector Energy Intensity Reductions in 1988–1999	45
7.5. Factor Effect and Residual Energy Intensity for States with the Largest Transportation Sector Energy Intensity Reductions in 1988–1999	46
8.1. Potential Energy Intensity Reductions If All States Replicated the Residuals Performance of the Top- and Bottom-Ranked States	48

Tables

3.1. Possible Factors Associated with Changes in Energy Intensity, by Energy-Consuming Sector	18
5.1. Observed Effect of Factors on Changes in Energy Intensity: Total Energy Consumption	24
5.2. Observed Effect of Factors on Changes in Energy Intensity: Industrial Sector	26
5.3. Observed Effect of Factors on Changes in Energy Intensity: Commercial Sector	27
5.4. Observed Effect of Factors on Changes in Energy Intensity: Residential Sector	29
5.5. Observed Effect of Factors on Changes in Energy Intensity: Transportation Sector	31
5.6. Average Percent Change in Energy Intensity for Each Energy-Consuming Sector, 1977–1987 Versus 1988–1999	31
5.7. Average Percent Impact of Factors on the Change in Energy Intensity for Each Energy-Consuming Sector, 1977–1987 Versus 1988–1999	32
7.1. Ranking of States in Reductions in Overall Energy Intensity and Residuals, 1977–1987 Versus 1988–1999	38
7.2. Residual-Reduction Rankings by Sector for States with the Highest Overall Residual Reduction	39
7.3. Ranking of States in Reductions in Industrial Energy Intensity and Residuals, 1977–1987 Versus 1988–1999	40
7.4. Ranking of States in Reductions in Commercial Energy Intensity and Residuals, 1977–1987 Versus 1988–1999	42
7.5. Ranking of States in Reductions in Residential Energy Intensity and Residuals, 1977–1987 Versus 1988–1999	44
7.6. Ranking of States in Reductions in Transportation Energy Intensity and Residuals, 1977–1987 Versus 1988–1999	46
A.1. Industrial Sector Regression Analysis Variables and Data Sources Used to Construct the Variables	54
A.2. Commercial Sector Regression Analysis Variables and Data Used to Construct the Variables	55
A.3. Residential Sector Regression Analysis Variables and Data Used to Construct the Variables	56
A.4. Transportation Sector Regression Analysis Variables and Data Used to Construct the Variables	57
B.1. Total Energy Intensity Regression Variables	60
B.2. Industrial Sector Energy Intensity Regression Variables	62
B.3. Commercial Sector Energy Intensity Regression Variables	65
B.4. Residential Sector Energy Intensity Regression Variables	68
B.5. Transportation Sector Energy Intensity Regression Variables	71
C.1. Predicted Average Annual Changes in Energy Intensity Due to Various Factors, 1988–1999, Using Extrapolation Method	75

C.2.	Predicted Average Annual Changes in Energy Intensity Due to Various Factors, 1988–1999, Using Prediction Method	76
D.1A.	Energy Intensity Analysis Data for the Entire Study Period 1977–1999: Industrial, Commercial, and Residential Sectors	80
D.1B.	Energy Intensity Analysis Data for the Entire Study Period 1977–1999: Transportation Sector and Total Aggregate	82
D.2A.	Energy Intensity Analysis Data for the Subperiod 1977–1988: Industrial, Commercial, and Residential Sectors	84
D.2B.	Energy Intensity Analysis Data for the Subperiod 1977–1988: Transportation Sector and Total Aggregate	86
D.3A.	Energy Intensity Analysis Data for the Subperiod 1988–1999: Industrial, Commercial, and Residential Sectors	88
D.3B.	Energy Intensity Analysis Data for the Subperiod 1988–1999: Transportation Sector and Total Aggregate	90

Summary

The National Energy Policy (NEP) released by the Bush administration in 2001 calls for continued reductions in *energy intensity*, which is typically defined as *energy consumption per dollar of gross economic output*. This study helps to identify states in which energy intensity has declined most sharply after taking into account non-policy-related factors that influence changes in energy intensity.

The analysis in this report is a first step toward understanding

- how changes (i.e., increases or decreases) in energy intensity differed across states over the past two decades
- how much of those changes is attributable to factors we can measure
- how much of those changes is potentially due to unobserved factors, which could possibly include state-level energy policies and actions.

States vary significantly in how they use energy, which is well illustrated by the changes in energy use by state over the past 20 or so years. In absolute terms, energy intensity varies substantially among states, but the magnitude and direction of change in energy intensity also vary significantly.

Analysis of energy intensity in the United States is often done at the national or energy-consuming-sector level. Because there is significant variation in energy intensity among states, we recognized that having more-disaggregate data could provide a more-robust set of analyses that may uncover additional information on what affects changes in energy intensity.

In this report, we examine changes in energy intensity in each of the 48 contiguous states, and we examine changes in energy intensity in the states' residential, commercial, industrial, and transportation energy-consuming sectors over the 1977–1999 study period. In attempting to better understand the variation in changes in energy intensity among states, we identified a number of factors that may explain why some states had different patterns of energy intensity than others. Those factors include:

- Energy prices
- Composition of an economic sector's output (e.g., the mix or type of industrial or commercial activities)

- Capacity utilization
- Capital investment and new construction
- Population and demographics
- Climate
- Technological innovation
- Energy policies and actions of national, state, and local governments.

The primary goal of this study is to measure how energy intensity varies across and within states, net of the effects of energy prices and other measured determinants of energy intensity. To this end, we use econometric techniques to model energy intensity as a function of four components:

- Measured variables (which we call the “factor effect”)
- Fixed differences across states—i.e., unmeasured factors that are fixed in time but vary across states
- An aggregate time trend—i.e., unmeasured factors common to all states (which we call the “common effect”)
- A “residual energy intensity” that varies across and within states.

In this report, we focus on residual energy intensity, which is a given state’s energy intensity that cannot be explained by observed factors or by overall time trends. We do not know exactly what is “contained” in the residual, but we assume that it may partly represent unobserved differences in energy-related policy both across and within states over time.

We use estimated average annual percentage changes in energy intensity to rank the states in two ways: First, we rank states simply by their average annual percent change in observed energy intensity; second, we rank states by their average annual percent change in residual energy intensity. Thus, the second ranking tells us which states experienced the largest declines in energy intensity net of changes in observed factors.

We show which factors are important to understanding the variations in energy intensity among the four major energy-consuming sectors—residential, commercial, industrial, and transportation—and the variations in energy intensity over time. By examining the effect that certain factors have on changes in energy intensity in the energy-consuming sectors, we can explain large amounts of the variation among states and can begin to understand how those factors can affect energy use in each state. Clearly, energy prices and the structure of the economy are important factors in energy use, and to the extent

that states can influence these factors, they can have some influence on energy use. Certain common effects are likely to continue absent any state actions, although, as we show in this report, those common effects differ over time.

We report on the states that had the greatest reductions in energy intensity over the full study period, 1977–1999, and over two subperiods, 1977–1987 and 1988–1999. We show results by total energy intensity and by each of the four major energy-consuming sectors. For each of those sectors, we list the top-ranked states in terms of actual reductions in energy intensity and reductions in residuals. For example, Figure S.1 illustrates the amount of the common effect, factor effect, and residual energy intensity for the five states with the greatest residual reduction in 1988–1999. These states had significant reductions in energy intensity over this period and had annual reductions in residuals or unexplained reductions in energy intensity that were more than 0.7 percent above what we would have predicted after taking into account the factor effects.

We also present some estimates of future possibilities for trends in energy intensity. If the unexplained reductions in energy intensity are dominated by the effects of policies and programs, and if the performance of the top five states were to be replicated in the other states, the United States could reduce its energy

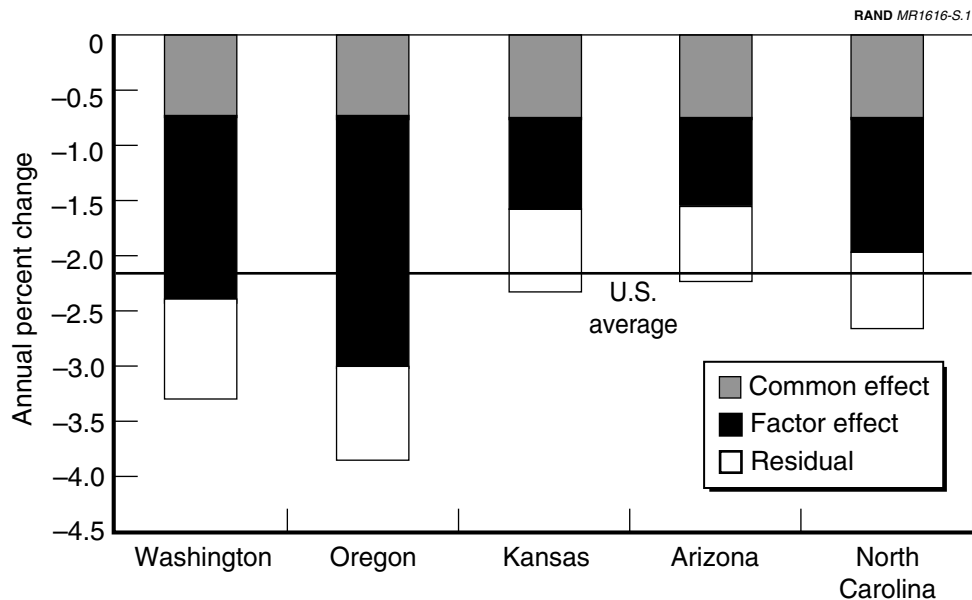


Figure S.1—Common Effect, Factor Effect, and Residual Energy Intensity for the Five Top-Ranked States in Residual Energy Intensity Reductions, 1988–1999

intensity overall by more than 3 percent per year, as opposed to the business-as-usual forecast from the Energy Information Administration of an approximately 1.5 percent reduction per year. The results from this study suggest that there may be opportunities for the DOE to enhance its involvement in helping states share information and provide guidance on effective state-level actions to reduce energy intensity.

Acknowledgments

This work was sponsored by the Department of Energy, Office of Energy Efficiency and Renewable Energy. We gratefully acknowledge the comments and reviews from a number of people who significantly improved the analysis and description of the results. Reviewers included Stephanie Battles from the Energy Information Administration; Paul DeCotis, Rachel Winters, Kathleen O'Bryan, and Erin Hogan from the New York State Energy Research and Development Authority; Keith Crane from RAND; and Jeffrey Dowd from the Department of Energy. We would also like to thank Debra Knopman for her helpful comments, Lisa Sheldone for helping with the review process, and Nancy DelFavero for her excellent editing work.

Acronyms

ACEEE	American Council for an Energy Efficient Economy
BEA	Bureau of Economic Analysis
Btu	British thermal unit
CEI	Commercial (sector) energy intensity
DOE	U.S. Department of Energy
DSM	Demand-side management
EI	Energy intensity
EIA	Energy Information Administration
F	Fahrenheit
F.I.R.E.	Finance, Insurance, and Real Estate
GDP	Gross domestic product
GSP	Gross state product
IEI	Industrial (sector) energy intensity
mmbtu	Million(s) British thermal units
NEP	National Energy Policy
NS	Not significant
OSTP	Office of Science and Technology Policy
REI	Residential (sector) energy intensity
SIC	Standard Industrial Classification
TEI	Transportation (sector) energy intensity