

University of Piraeus

**Energy Security:
Benjamin K. Sovacool's
Research 2009-2014**



John A. Paravantis

ASSOCIATE PROFESSOR

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Original research article

What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda

Benjamin K. Sovacool^{a,b,c,*}^a Business and Social Sciences, AU-Herning, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark^b Center for Energy Technologies, AU-Herning, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark^c Vermont Law School, Institute for Energy & The Environment, PO Box 96, 164 Chelsea Street, South Royalton, VT 05068-0444, United States

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ABSTRACT

Social science related disciplines, methods, concepts, and topics remain underutilized, and perhaps underappreciated, in contemporary energy studies research. To make this case, the article offers both **quantitative** and **qualitative data**. It begins with the quantitative part, providing a content analysis of **4444 research articles** involving **9549 authors** and **90,079 references** (from a smaller subsample) published in three leading energy journals from **1999 to 2013**. Within this vast sample, only 19.6 percent of authors reported training in any **social science** discipline, and less than 0.3 percent of authors reported disciplinary affiliations in areas such as **history, psychology, anthropology, and communication studies**. Only **12.6 percent of articles utilized qualitative methods** and less than 5 percent of citations were to social science and humanities journals. The article then shifts to the qualitative part, where it proposes a variety of methodological and topical areas, along with **75 research questions**, that could deepen and broaden energy research, connected in part to all of the articles in this special (inaugural) issue of *Energy Research & Social Science (ERSS)*. Readers from all disciplines are encouraged to read it—especially the parts dealing with areas and concepts outside of their own areas of expertise.

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A B S T R A C T

Social science related disciplines, methods, concepts, and topics remain underutilized, and perhaps underappreciated, in contemporary energy studies research. To make this case, the article offers both quantitative and qualitative data. It begins with the quantitative part, providing a content analysis of 4444 research articles involving 9549 authors and 90,079 references (from a smaller subsample) published in three leading energy journals from 1999 to 2013. Within this vast sample, only 19.6 percent of authors reported training in any social science discipline, and less than 0.3 percent of authors reported disciplinary affiliations in areas such as history, psychology, anthropology, and communication studies. Only 12.6 percent of articles utilized qualitative methods and less than 5 percent of citations were to social science and humanities journals. The article then shifts to the qualitative part, where it proposes a variety of methodological and topical areas, along with 75 research questions, that could deepen and broaden energy research, connected in part to all of the articles in this special (inaugural) issue of *Energy Research & Social Science (ERSS)*. Readers from all disciplines are encouraged to read it—especially the parts dealing with areas and concepts outside of their own areas of expertise.

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Table 1
Sample of articles included in this content analysis.

Year	Energy Policy				Electricity Journal		The Energy Journal	
	# Total articles	% Articles in sample	# Articles in sample	# Authors in sample	# Articles	# Authors	# Articles	# Authors
1999	66	100	66	145	83	134	38	89
2000	91	100	91	183	69	112	23	37
2001	105	100	105	248	74	135	20	37
2002	106	100	106	205	76	123	20	33
2003	125	100	125	256	75	131	19	38
2004	146	100	146	334	69	126	23	48
2005	179	100	179	425	67	124	30	60
2006	323	100	323	751	73	140	78	211
2007	539	33	180	454	70	141	37	75
2008	424	33	142	345	63	121	32	57
2009	579	33	191	446	70	125	53	113
2010	791	33	261	590	78	140	45	92
2011	797	33	263	601	85	155	44	94
2012	822	33	271	642	78	131	34	71
2013	1039	33	343	788	89	162	37	81
Total	6132	45.5	2792	6413	1119	2000	533	1136

Table 2Twenty categories for **author** training.

Category	Examples of included disciplines
Anthropology	Anthropology, Cultural Studies, Ethnology
Business	Business, Management Science, Finance
Communication	Communication Studies, Rhetoric, Mass Media
Computer Science	Computer Science, Information Technology, Technical Institutes
Development	Development Studies, Area Studies, Social Development
Economics	Economics, Statistics, Mathematics, Econometrics, Industrial Organization
Energy	Energy Institutes, Energy Policy Studies, Energy and Resources Studies, Petroleum and Minerals, Mineralogy
Engineering	Electrical Engineering, Civil Engineering, Mechanical Engineering, etc.
Gender	Feminism, Women's Studies, Gender Studies, Family Studies
Geography	Physical Geography, Remote Sensing, Geographic Information Systems, Human Geography, Cartography
Hard Sciences	Physics, Astronomy, Cosmology, Chemistry, Geology
History	History, Social History, Historiography
Law	Law, Criminology, Penology, Legal Studies
Life Sciences	Biology, Ecology, Epidemiology, Botany, Environmental Sciences
Philosophy	Philosophy, Ethics, Metaphysics, Applied Philosophy, Epistemology
Planning/Architecture	Planning, Architecture, Real Estate, Urban Studies, Landscape Planning, Design
Political Science	Political Science, International Relations, International Affairs, Political Economy, Geopolitics, Civics, Peace Studies, Democracy Studies, Psephology
Psychology	Psychology, Psychiatry, Social Psychology, Applied Psychology
Public Policy	Public Policy, Public Administration, Policy Studies
Sociology	Sociology, Environmental Sociology, Human–Environment Interactions, Human Ecology, Demography, Collective Behavior

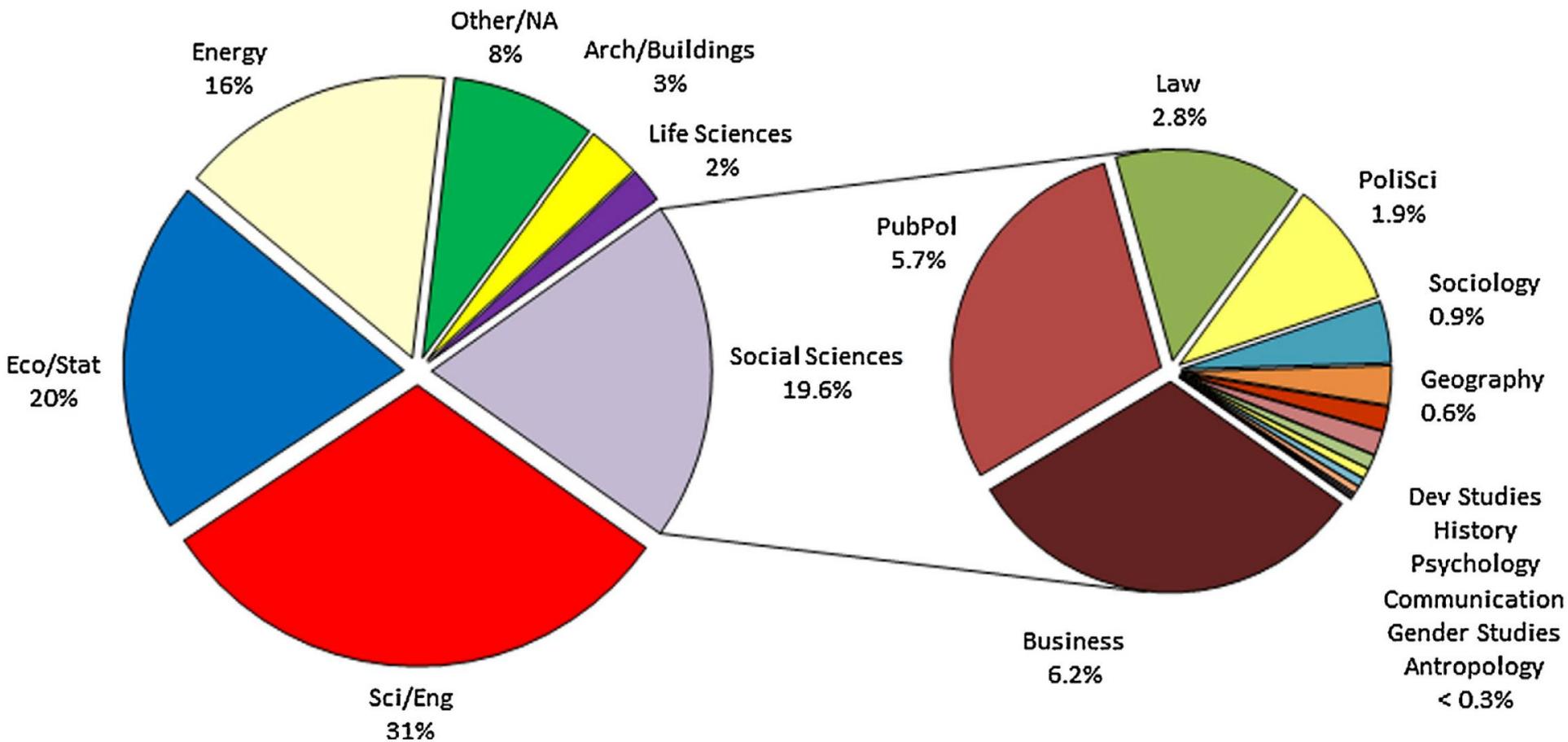


Fig. 1. Disciplinary affiliation for energy studies journal articles, 1999–2013 ($n = 9597$). *Note:* Sums may not equal 100% due to independent rounding.

Table 3

Fifteen categories for article topics.

Category	Included topics
Markets	Energy Markets, Restructuring and Liberalization, Privatization, Market Barriers, Market Failure
Supply and Demand	Fuel Supply and Demand, Fuel Reserves, Projections of Future Energy Demand
Behavior	User Behavior, End Users, Attitudes, Values, Individual or Household Consumption Patterns
Climate Change	Climate Change, Greenhouse Gas Emissions, Mitigation, Adaptation, Geo-Engineering
Pollution	Water Pollution, Air Pollution, Land Pollution, Waste, Effluents
Land Use	Agriculture, Forestry, Urban Planning, Mining, Land Use Planning, Geography, Spatial Attributes
R&D	Research and Development, Research Development and Demonstration, Market Diffusion, Innovation, Technological Learning, Subsidies
Industry	Industrial Processes, Manufacturing, Refining, Petrochemicals, Paper & Pulp Processing
Politics	Energy Security, Geopolitics, Security of Supply, Democracy, International Relations, Political Economy
Pricing and Prices	Prices, Pricing Schemes, Rate Design, Tariffs
Institutions	Energy Governance, Energy Institutions, Energy Organizations
Investment	Foreign Direct Investment, Trade, Technology Transfer, Financing, Risk
Public Policy	Public Policy Mechanisms such as Carbon Credits, Carbon Taxes, Subsidies, Tax Credits, Loans, Feed-in Tariffs
Development	Developing Countries, Energy and Development, the Development Process, Poverty, Rural Energy Use
Other	Other

Table 4

General statistics for energy studies journal articles, 1999–2013.

Year	Number of total articles	Number of authors	Number of disciplinary affiliations	Number of institutional affiliations	Number of disclosed funding sources	Number of methodological approaches	Number of country case studies	Number of discussed technologies	Number of discussed topics	Number of references ^a
1999	187	368	346	355	196	206	206	296	425	1780
2000	183	332	281	277	190	213	170	253	325	2451
2001	199	420	500	413	224	225	239	415	635	2940
2002	202	361	374	311	220	211	207	266	519	2879
2003	219	425	448	389	235	231	252	350	594	3288
2004	238	508	597	483	295	262	293	473	822	4778
2005	276	609	653	548	296	299	290	439	610	5539
2006	474	1102	932	1016	532	499	540	1080	1266	12,833
2007	287	670	626	504	332	320	329	809	773	5221
2008	237	523	470	470	147	275	241	772	698	5108
2009	314	684	707	680	334	383	322	938	903	6820
2010	384	822	799	810	414	469	401	1121	1250	8486
2011	392	850	852	842	398	445	410	1219	1298	8534
2012	383	844	883	809	420	414	390	1335	1258	8576
2013	469	1031	1129	974	505	560	525	1490	1432	10,846
Total	4444	9549	9597	8881	4738	5012	4815	11,256	12,808	90,079

^a Includes only *Energy Policy* for all years and the *Energy Journal* from 2003 to 2013.

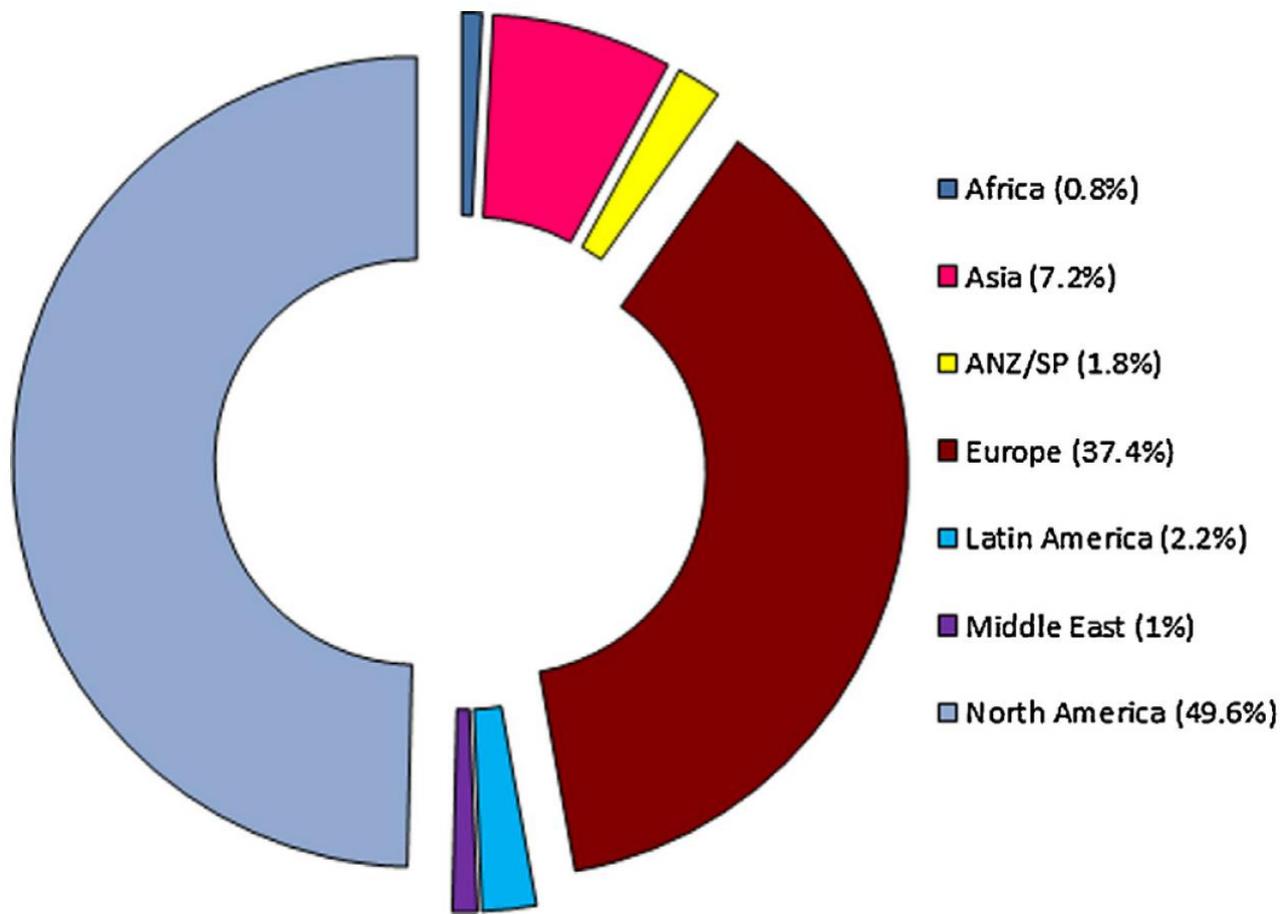


Fig. 2. Country affiliation for energy studies journal authors, 1999–2013 ($n = 9549$).
Note: Sums may not equal 100% due to independent rounding. ANZ/SP refers to Australia, New Zealand, and the South Pacific.

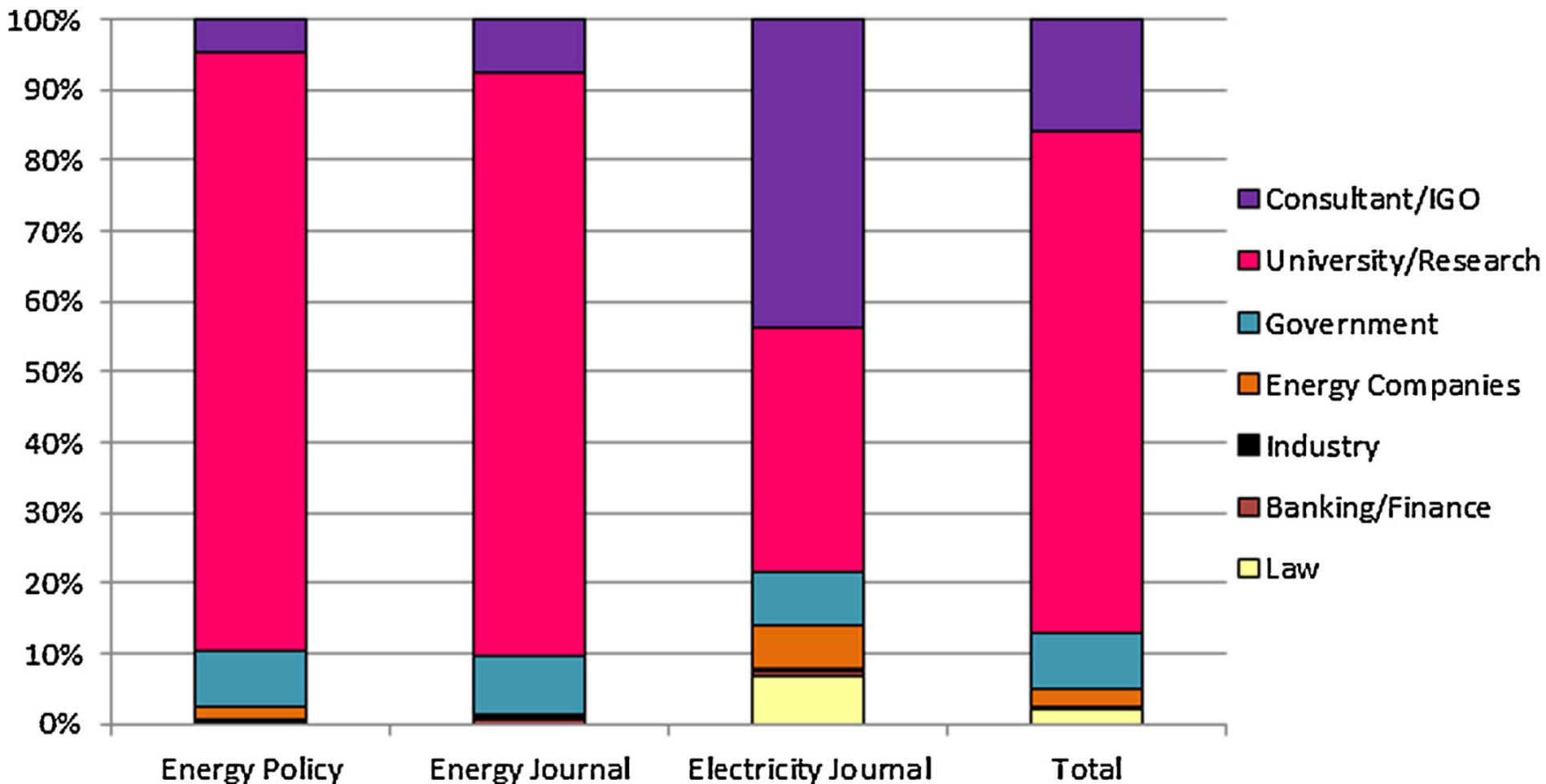


Fig. 3. Institutional affiliations for energy studies journal articles, 1999–2013 ($n = 8881$).

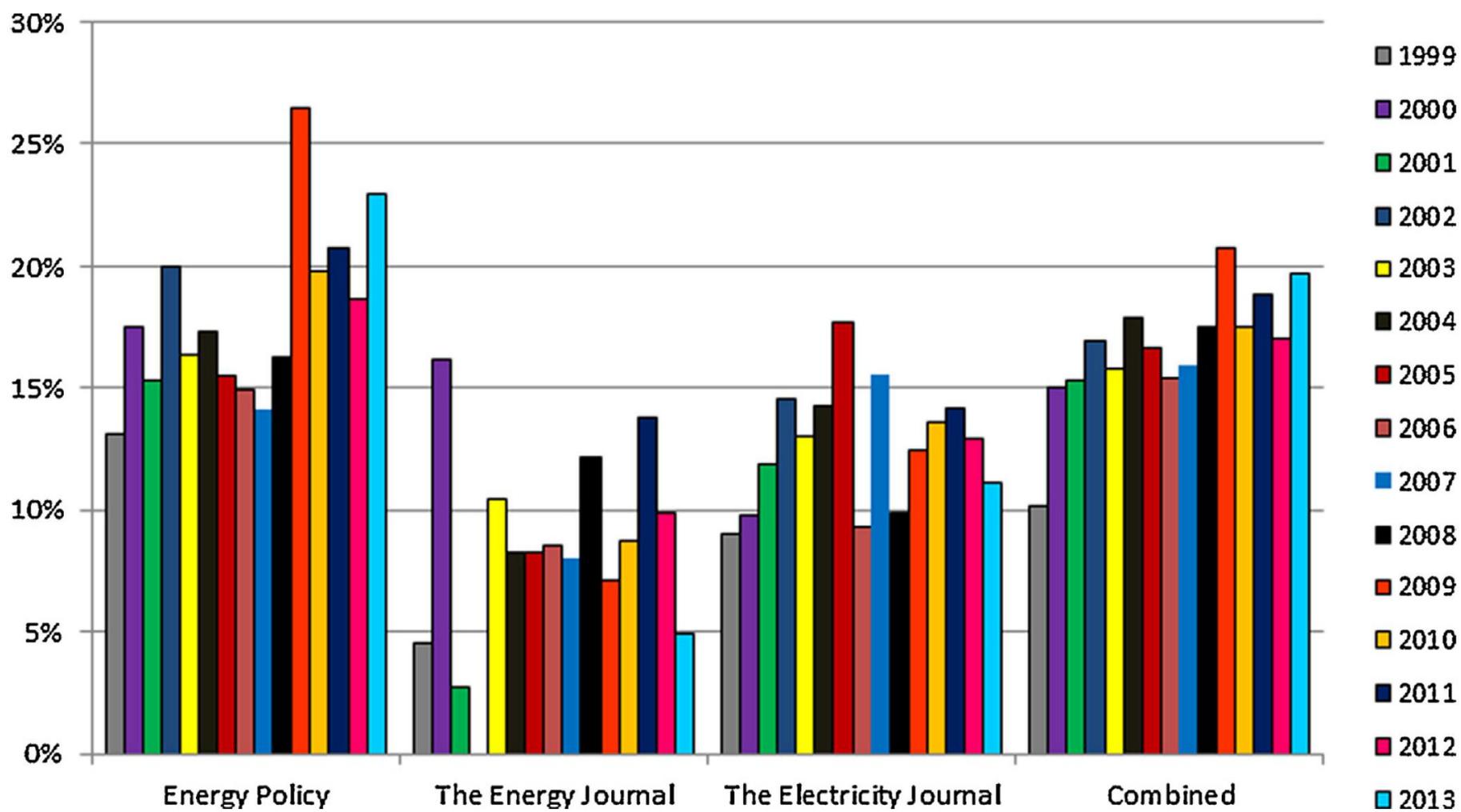


Fig. 4. Share of female authors for energy studies journal articles, 1999–2013 ($n = 9549$).

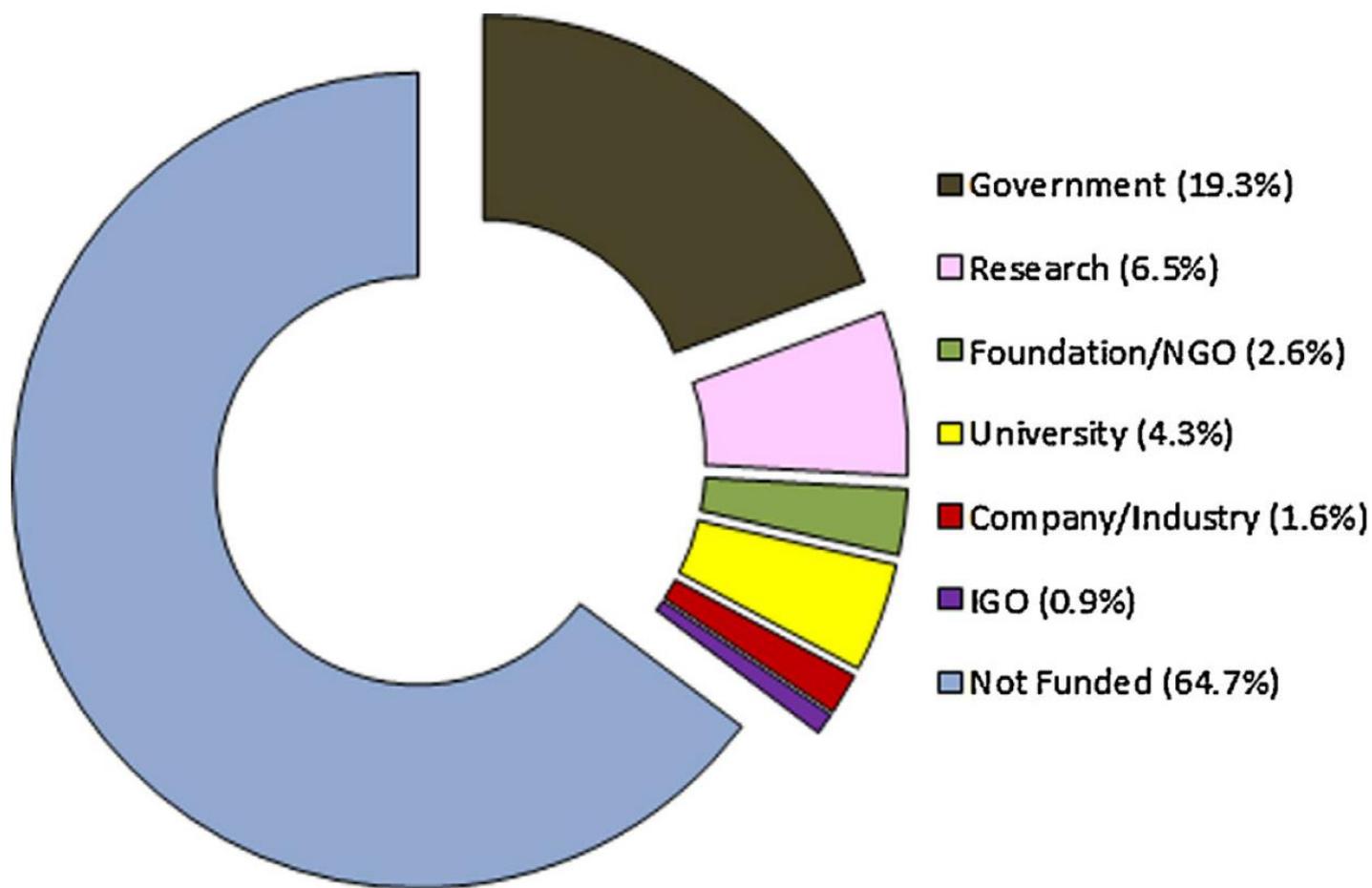


Fig. 5. Disclosed funding sources for energy studies journal articles, 1999–2013 ($n = 4738$). *Note:* Sums may not equal 100% due to independent rounding.

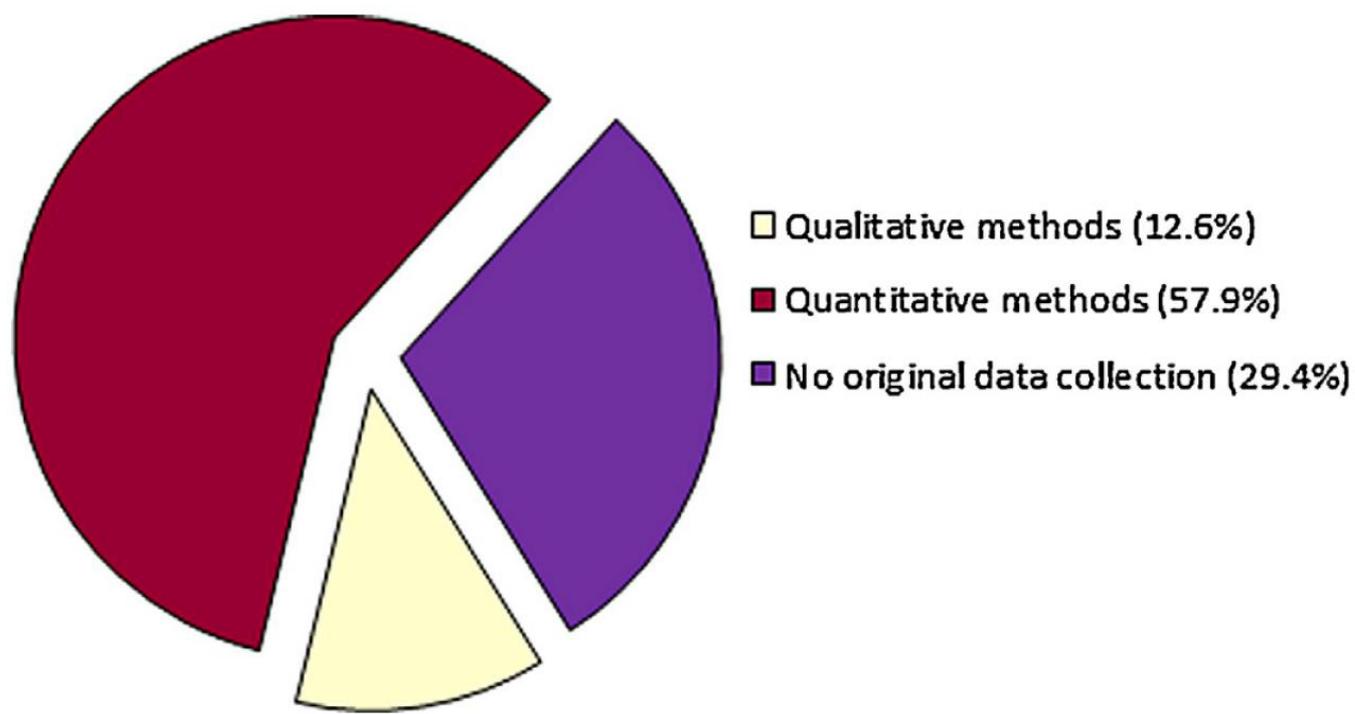


Fig. 6. Methodological approaches of energy studies journal articles, 1999–2013 ($n = 5012$). *Note:* Sums do not equal 100% due to independent rounding. “Qualitative methods” refer to original data collected through research interviews, surveys, questionnaires, or field research. “Quantitative methods” refer to original data collected through economic modeling, forecasting, econometric analysis, programming, statistical analysis, input/output analysis, cost benefit analysis, lifecycle assessments, remote sensing, and other similar tools.

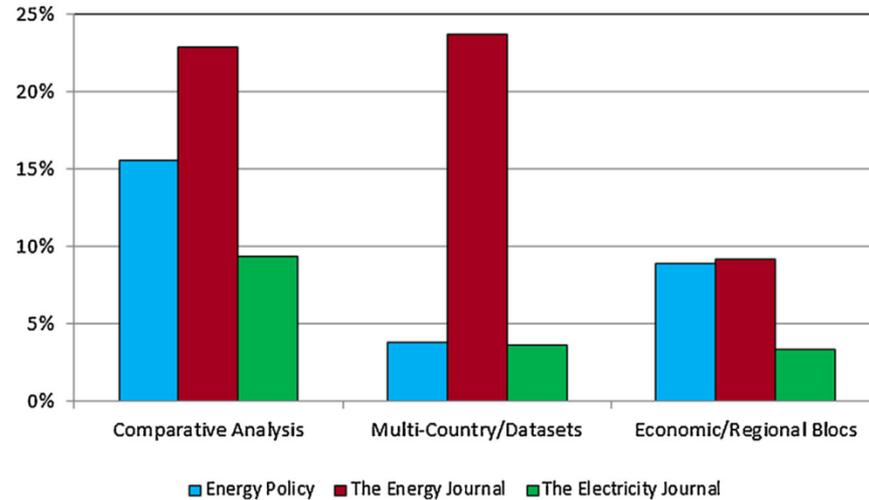
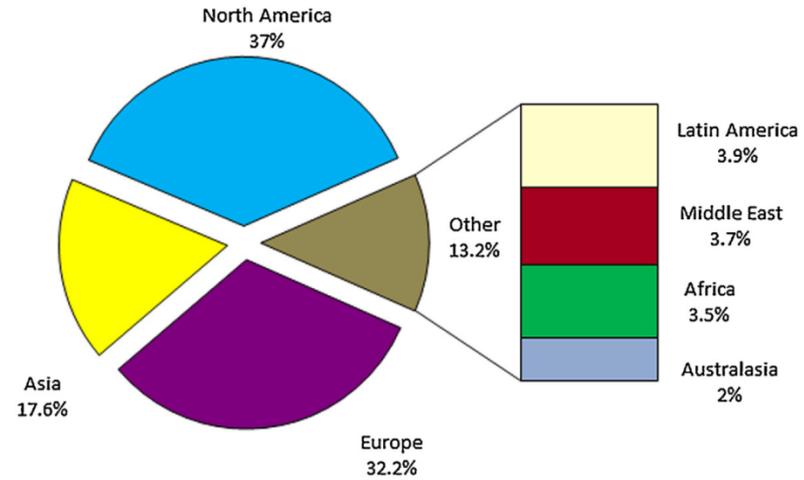


Fig. 7. Country and comparative case study focus for energy studies journal articles, 1999–2013 ($n=4815$). Note: Sums may not equal 100% due to independent rounding

Table 5
 Top five specific technology foci for three energy studies journals, 1999–2013.

Energy Policy		The Energy Journal		Electricity Journal	
Electricity	17.8%	Petroleum	32.2%	Electricity	90.4%
Energy Efficiency	15.8%	Electricity	20.6%	Natural Gas/LNG	22.7%
Natural Gas/LNG	14.5%	Natural Gas/LNG	17.2%	Energy Efficiency	16.8%
Petroleum	14.4%	Energy Efficiency	12.8%	Coal/Clean Coal	15.6%
Coal/Clean Coal	9.4%	Coal/Clean Coal	11.3%	Nuclear Power	12.9%

Note: Percentages will not match the sums of articles or topics because many articles focused on multiple technologies at once.

Energy Policy

Electricity	17.8%
Energy Efficiency	15.8%
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The Energy Journal

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Electricity Journal

Electricity	90.4%
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Coal/Clean Coal	15.6%
Nuclear Power	12.9%

Table 6

Top five specific topical foci for three energy studies journals, 1999–2013.

Energy Policy		The Energy Journal		Electricity Journal	
Climate Change	14%	Public Policy	16.5%	Energy Markets	26.1%
Supply and Demand	13.6%	Pricing and Prices	14.9%	Pricing and Prices	19.2%
Energy Markets	12.5%	Climate Change	15.6%	Investment and Trade	13.4%
Investment and Trade	11.7%	Energy Markets	15.2%	Public Policy	8.1%
Industry	9.5%	Supply and Demand	7.9%	Institutions	7.8%

Note: Percentages will not match the sums of articles or topics because many articles focused on multiple topics at once.

Energy Policy

Climate Change	14%
Supply and Demand	13.6%
Energy Markets	12.5%
Investment and Trade	11.7%
Industry	9.5%

The Energy Journal

Public Policy	16.5%
Pricing and Prices	14.9%
Climate Change	15.6%
Energy Markets	15.2%
Supply and Demand	7.9%

Electricity Journal

Energy Markets	26.1%
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Investment and Trade	13.4%
Public Policy	8.1%
Institutions	7.8%

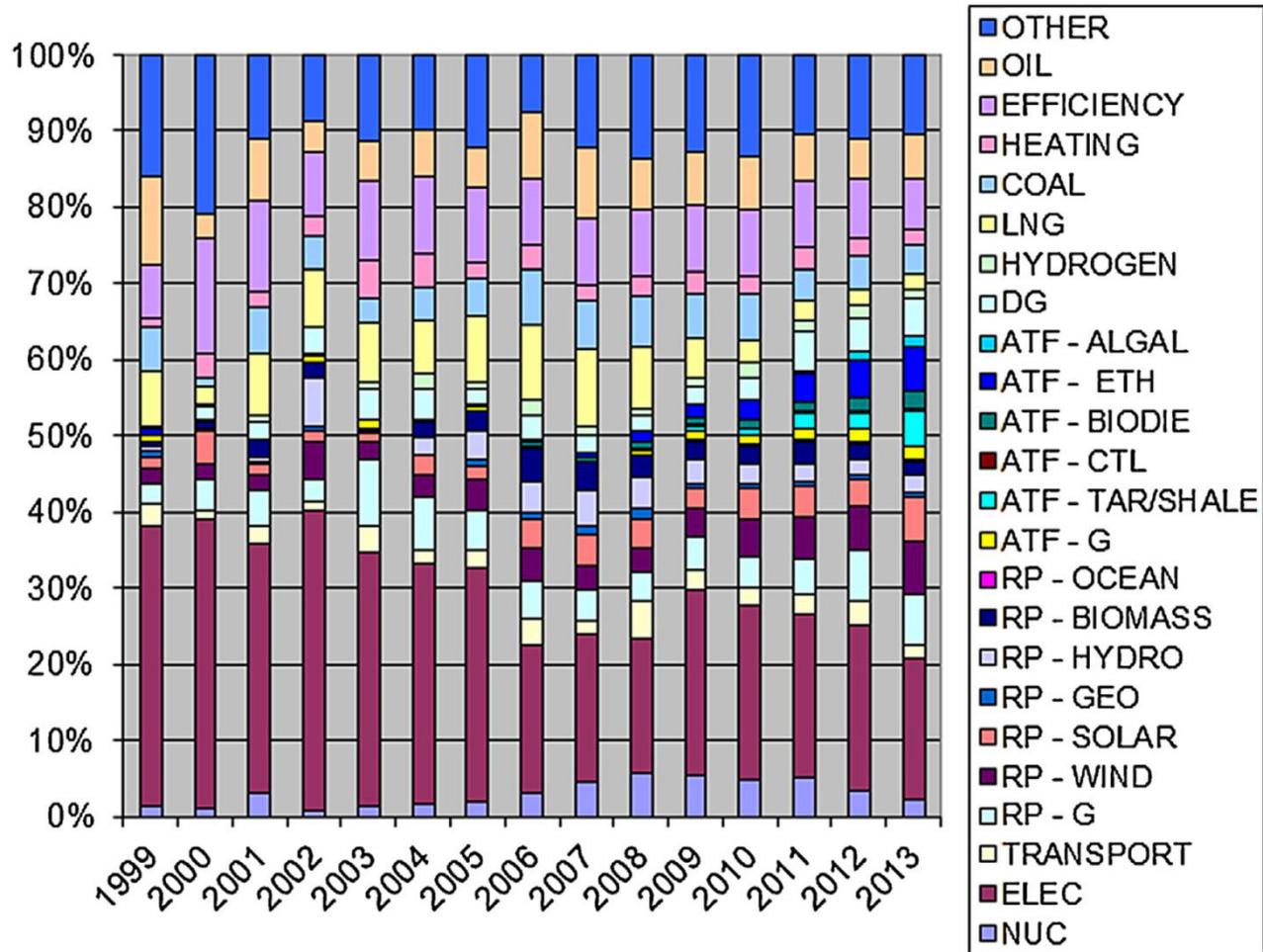


Fig. 8. Technology focus of energy studies journal articles, 1999–2013 ($n = 11,256$). *Note:* NUC, “nuclear power”; ELEC, “Electricity” (inclusive of generation, transmission, and distribution); RP, “renewable power”; ATF, “alternative transport fuels”; “G”, “general.” “LNG” refers to natural gas but not shale gas, which is included in “ATF–Tar/Shale”; DG, “distributed generation.”

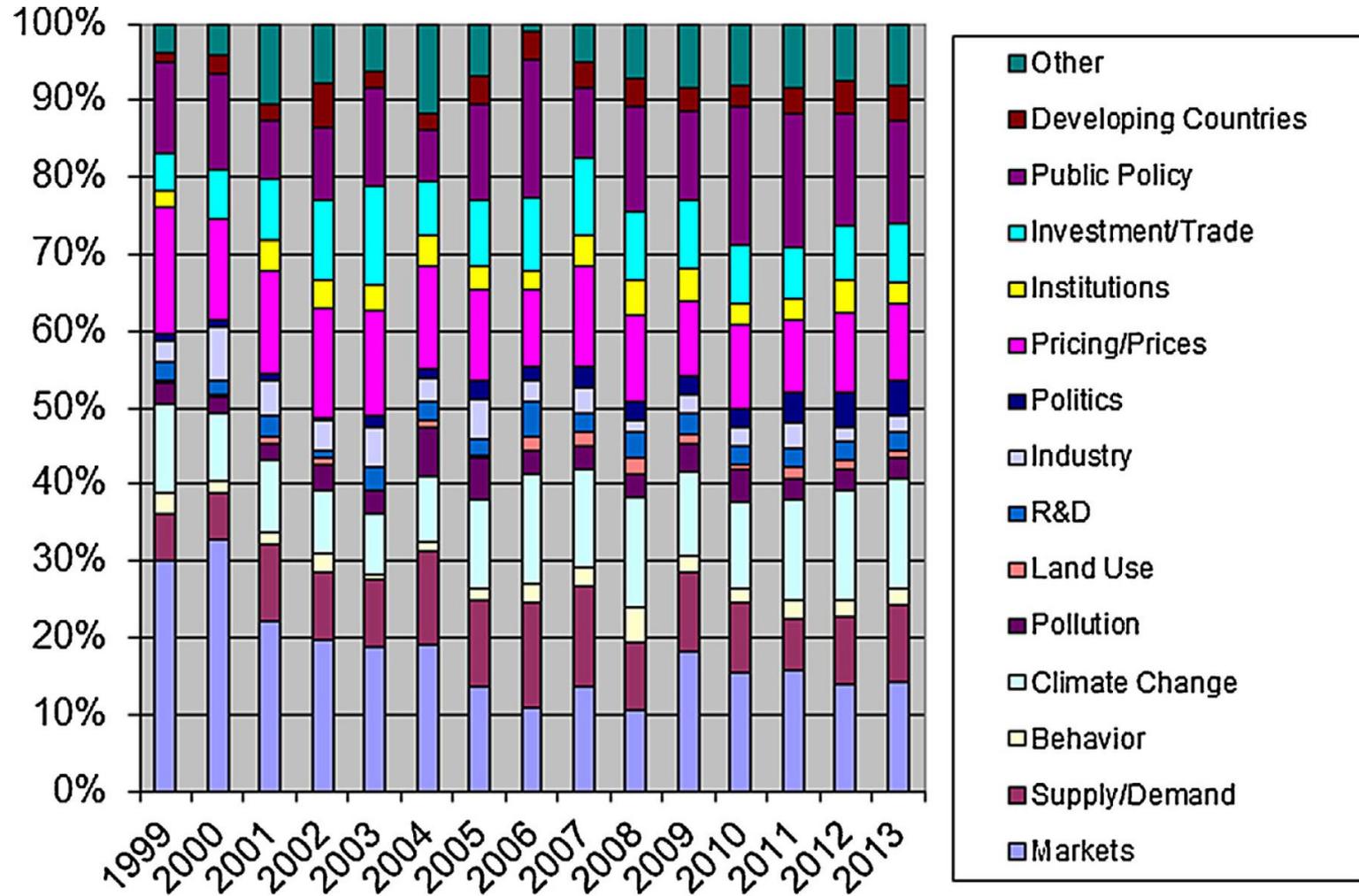


Fig. 9. Topic focus for energy studies journal articles, 1999–2013 ($n = 12,808$).

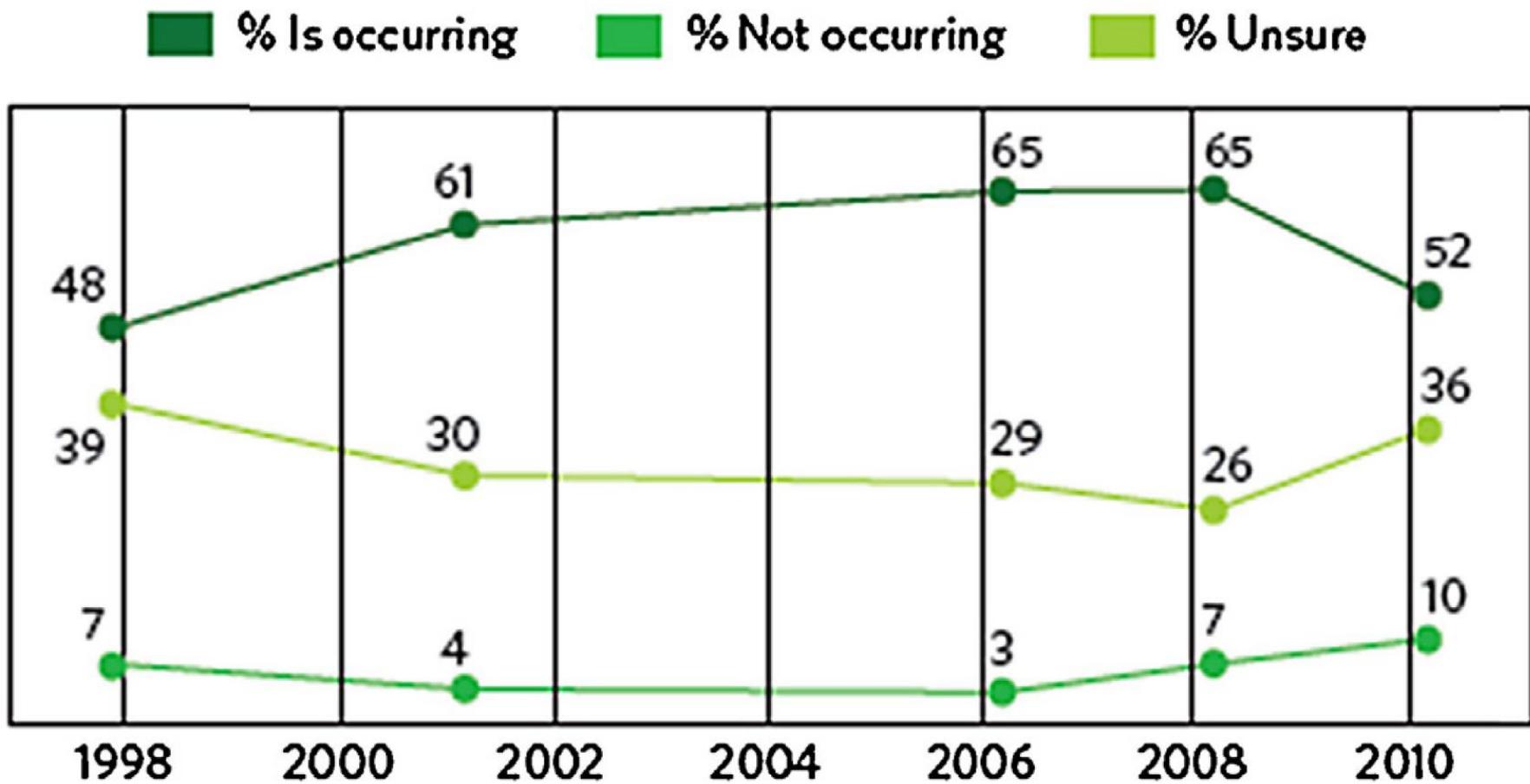


Fig. 13. Opinions about climate change in the United States, 1998–2011.
 Source: [112].

Table 13

Comparative greenhouse gas lifecycle estimates for sources of electricity.

Technology	Capacity/configuration/fuel	Mean estimate (gCO ₂ e/kWh)
Hydroelectric	3.1 MW, reservoir	10
Biogas	Anaerobic digestion	11
Hydroelectric	300 kW, run-of-river	13
Solar thermal	80 MW, parabolic trough	13
Biomass	Forest wood co-combustion with hard coal	14
Biomass	forest wood steam turbine	22
Biomass	Short rotation forestry co-combustion with hard coal	23
Biomass	Forest wood reciprocating engine	27
Biomass	Waste wood steam turbine	31
Wind	Various sizes and configurations	34
Biomass	Short rotation forestry steam turbine	35
Geothermal	80 MW, hot dry rock	38
Biomass	Short rotation forestry reciprocating engine	41
Solar photovoltaic	Various sizes and configurations	50
Nuclear	Various reactor types	66
Natural gas (conventional)	Various combined cycle turbines	443
Natural gas (fracking)	Combined cycle turbines using fuel from hydraulic fracturing	492
Natural GAS (LNG)	Combined cycle turbines utilizing LNG	611
Fuel cell	Hydrogen from gas reforming	664
Diesel	Various generator and turbine types	778
Heavy oil	Various generator and turbine types	778
Coal	Various generator types with scrubbing	960
Coal	Various generator types without scrubbing	1050

Table 13

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Competing Dimensions of Energy Security: An International Perspective

Benjamin K. Sovacool, Marilyn A. Brown

January 13, 2009

Abstract: How well are industrialized nations doing in terms of their energy security? Without a standardized set of metrics, it is difficult to determine the extent that countries are properly responding to the emerging energy security challenges related to climate change, growing dependence on fossil fuels, population growth and economic development. In response, we propose the creation of an Energy Security Index to inform policymakers, investors and analysts about the status of energy conditions. Using the United States and 21 other member countries of the Organization for Economic Cooperation and Development (OECD) as an example, and looking at energy security from 1970 to 2007, our index shows that only four countries—Belgium, Denmark, Japan, and the United Kingdom—have made progress on multiple dimensions of the energy security problem. The remaining 18 have either made no improvement or are less secure. To make this argument, the first section of

either made no improvement or are less secure. To make this argument, the first section of the article surveys the scholarly literature on energy security from 2003 to 2008 and argues that an index should address accessibility, affordability, efficiency, and environmental stewardship. Because each of these four components is multidimensional, the second section discusses ten metrics that comprise an Energy Security Index: oil import dependence, percentage of alternative transport fuels, on-road fuel economy for passenger vehicles, energy intensity, natural gas import dependence, electricity prices, gasoline prices, sulfur dioxide emissions, and carbon dioxide emissions. The third section analyzes the relative performance of four countries: Denmark (the top performer), Japan (which performed well), the United States (which performed poorly), and Spain (the worst performer). The article concludes by offering implications for policy. Conflicts between energy security criteria mean that advancement along any one dimension can undermine progress on another dimension. By focusing on a 10-point index, public policy can better illuminate such tradeoffs and can identify compensating policies.

Table 1: Defining and Measuring Energy Security

Criteria	Underlying Values	Explanation	Metrics
<i>Availability</i>	Independence, diversification, reliability	Diversifying the fuels used to provide energy services as well as the location of facilities using those fuels, promoting energy systems that can recover quickly from attack or disruption, and minimizing dependence on foreign suppliers	Oil import dependence; Natural gas import dependence; Availability of alternative fuels
<i>Affordability</i>	Equity	Providing energy services that are affordable for consumers and minimizing price volatility	Retail electricity prices; Retail gasoline/petrol prices
<i>Energy and Economic Efficiency</i>	Innovation, resource custodianship, minimization of waste	Improving the performance of energy equipment and altering consumer attitudes	Energy intensity; Per capita electricity use; Average fuel economy for passenger vehicles
<i>Environmental Stewardship</i>	Sustainability	Protecting the natural environment and future generations	Sulfur dioxide emissions; Carbon dioxide emissions

Figure 1: Conflicts Between Components of Energy Security

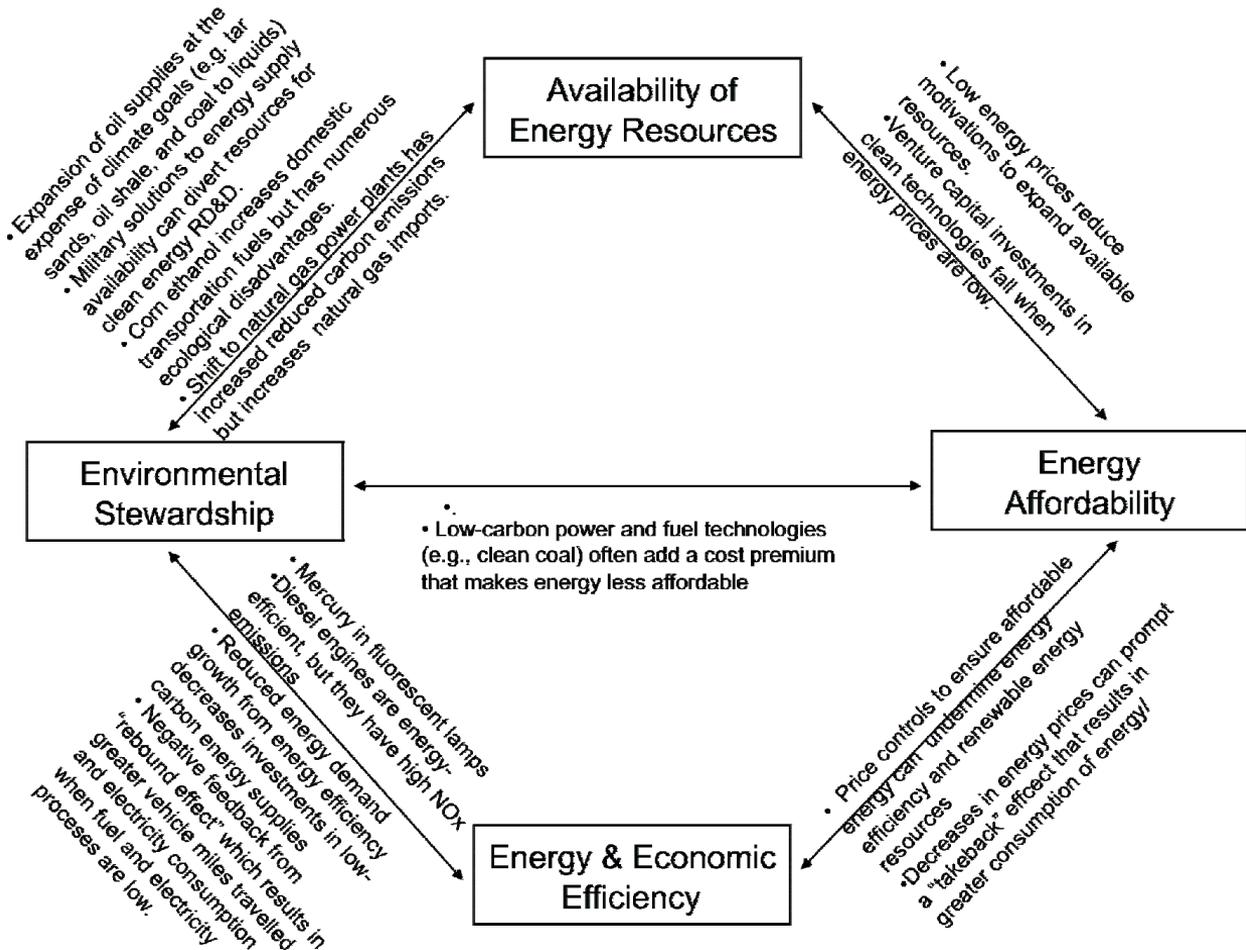


Table 2: Energy Security Performance Index for 22 OECD Countries, 1970 (in \$2007)⁶⁴

	Oil import dependence (%)	Alternative fuels (%)	On-road fuel economy (passenger vehicles mpg-e)	Energy intensity (thousand BTU/US\$GDP)*	Electricity use (kWh/capita)	Natural gas import dependence (%)	Nominal electricity retail prices (US¢/kWh)	Nominal gasoline prices (US\$/liter)	SO ₂ emissions (million tons)	CO ₂ emissions (million tons)
Australia	67%	3.9%	17	10.3	3,919	0%	3.7	0.26	1.6	143
Austria	57%	5.7%	21	8.5	3,302	34%	18	1.32	0.4	49
Belgium	100%	1.6%	22	12.2	3,399	99%	18.5	1.74	1.2	118
Canada	46%	2.7%	14	18.7	9,529	1%	3.7	0.37	4.1	340
Denmark	99%	1.9%	24	8.8	3,211	0%	9.5	0.42	0.3	56
Finland	100%	2.3%	22	12.6	4,885	100%	5.3	0.53	0.4	40
France	98%	3.7%	28	8.7	2,882	35%	7.9	0.74	3.5	435
Germany	92%	3.6%	24	9.8	2,962	24%	15.9	1.16	6.9	984
Greece	99%	1.7%	21	6.0	1,118	0%	2.1	0.58	0.3	25
Ireland	98%	2.8%	22	9.0	1,956	0%	6.9	0.58	0.2	22
Italy	97%	1.3%	28	7.1	2,262	0%	6.3	0.42	2.6	295
Japan	100%	1.8%	20	7.8	3,445	32%	48.6	1.27	5.1	743
Netherlands	97%	2.0%	25	12.9	3,110	0%	15.3	1.00	1.4	130
New Zealand	100%	4.4%	19	11.0	4,941	0%	3.17	0.48	0.1	14
Norway	100%	2.5%	23	16.4	14,785	0%	2.6	0.42	0.2	24
Portugal	99%	2.0%	23	4.4	830	0%	20.6	1.59	0.1	15
Spain	99%	2.7%	27	7.0	1,623	85%	5.8	0.37	1.1	121
Sweden	100%	2.5%	20	13.7	8,048	0%	3.2	0.32	0.9	831
Switzerland	100%	3.1%	23	7.6	4,693	100%	4.0	1.59	0.1	39
Turkey	53%	2.3%	15	5.0	241	0%	21.1	0.11	0.8	42
UK	100%	2.3%	21	9.9	4,489	7%	5.3	0.58	8.6	630
United States	22%	4.9%	13	14.7	8,022	4%	7.0	0.42	31.2	4,200
Median	99%	2.5%	22	9.0	3,302	1%	6.9	0.6	0.9	118
Mean	84%	2.6%	21	9.6	4,079	24%	10.5	0.7	3.2	416

Table 3: Energy Security Performance Index for 22 OECD Countries, 2007⁶⁵

	Oil import dependence (%)	Alternative fuels (%)	On-road fuel economy (passenger vehicles mpg-e)	Energy intensity (thousand BTU/US\$GDP)*	Electricity use (kWh/capita)	Natural gas import dependence (%)	Real electricity retail prices (US¢/kWh)	Real gasoline prices (\$/liter)	SO ₂ emissions (million tons)*	CO ₂ emissions (million tons)
Australia	37%	1.7%	26	9.0	11,309	0%	12.5	1.24	2.6	395
Austria	91%	3.7%	31	7.0	8,090	95%	22.6	1.81	0.2	73
Belgium	99%	1.9%	29	9.2	8,688	100%	16.5	2.20	1.3	117
Canada	0%	1.2%	23	13.8	16,766	0%	7.6	1.08	2.9	539
Denmark	0%	2.3%	30	5.2	6,864	0%	38.2	2.05	0.1	55
Finland	96%	1.9%	29	8.8	17,178	93%	17.1	2.12	0.3	67
France	96%	1.9%	32	7.2	7,585	97%	17.3	2.03	1.3	378
Germany	94%	1.9%	29	7.0	7,175	79%	23.1	2.10	2.4	823
Greece	99%	1.9%	29	6.8	5,372	99%	13.0	1.19	0.8	94
Ireland	100%	1.9%	29	4.9	6,500	86%	24.7	1.77	0.1	45
Italy	93%	2.5%	33	5.8	5,762	85%	27.2	2.06	1.5	448
Japan	97%	1.8%	22	6.5	8,220	93%	17.8	1.46	2.6	1,213
Netherlands	91%	1.9%	30	9.8	7,057	59%	24.2	2.28	1.0	178
New Zealand	69%	2.9%	29	9.1	9,746	0%	17.8	1.35	0.1	37
Norway	0%	1.9%	29	12.8	24,295	0%	17.5	2.32	0.6	37
Portugal	98%	1.9%	29	5.9	4,799	100%	23.3	2.07	0.2	56
Spain	98%	1.9%	31	7.1	6,213	100%	18.7	1.64	2.1	328
Sweden	99%	1.9%	28	9.1	15,230	100%	12.7	1.99	0.3	48
Switzerland	99%	1.9%	29	5.8	8,279	100%	15.6	1.65	0.1	44
Turkey	94%	3.7%	29	6.1	2,053	97%	15.8	2.60	2.1	240
UK	4%	3.7%	31	6.0	6,192	8%	22.7	2.07	1.6	536
United States	59%	2.9%	20	9.1	13,515	17%	10.3	0.82	17.8	5,697
Median	94%	1.9%	29	7.0	7,585	93%	17.8	2.0	1.0	117
Mean	72%	2.2%	27	7.4	8,890	64%	18.4	1.8	1.8	502

Table 4: Energy Security Performance Score, 1970 to 2007

	Oil import dependence (%)	Alternative fuels (%)	Fuel economy (new passenger vehicles mpg-e)	Energy intensity (thousand BTU/US\$GDP)*	Electricity use (kWh/capita)	Natural gas import dependence (%)	Nominal electricity retail prices (US¢/kWh)	Nominal gasoline prices (US\$/liter)	SO ₂ emissions (million tons)	CO ₂ emissions (million tons)	Final Score
Australia	+1	-1	+1	+1	-1	0	-1	-1	-1	-1	-3
Austria	-1	-1	+1	+1	-1	-1	-1	-1	+1	-1	-4
Belgium	+1	+1	+1	+1	-1	-1	+1	-1	-1	+1	+2
Canada	+1	-1	+1	+1	-1	+1	-1	-1	+1	-1	0
Denmark	+1	+1	+1	+1	-1	0	-1	-1	+1	+1	+3
Finland	+1	-1	+1	+1	-1	+1	-1	-1	+1	-1	0
France	+1	-1	+1	+1	-1	-1	-1	-1	+1	+1	0
Germany	-1	-1	+1	+1	-1	-1	-1	-1	+1	+1	-2
Greece	0	+1	+1	-1	-1	-1	-1	-1	-1	-1	-5
Ireland	-1	-1	+1	+1	-1	-1	-1	-1	+1	-1	-4
Italy	+1	+1	+1	+1	-1	-1	-1	-1	+1	-1	0
Japan	+1	0	+1	+1	-1	-1	+1	-1	+1	-1	+1
Netherlands	+1	-1	+1	+1	-1	-1	-1	-1	+1	-1	-2
New Zealand	+1	-1	+1	+1	-1	0	-1	-1	0	-1	-2
Norway	+1	-1	+1	+1	-1	0	-1	-1	-1	-1	-3
Portugal	+1	-1	+1	-1	-1	-1	-1	-1	-1	-1	-6
Spain	+1	-1	+1	-1	-1	-1	-1	-1	-1	-1	-6
Sweden	+1	-1	+1	+1	-1	-1	-1	-1	+1	+1	0
Switzerland	+1	-1	+1	+1	-1	0	-1	-1	0	-1	-2
Turkey	-1	+1	+1	+1	-1	-1	+1	-1	-1	-1	-2
UK	+1	+1	+1	+1	-1	-1	-1	-1	+1	+1	2
United States	-1	-1	+1	+1	-1	-1	-1	-1	+1	-1	-4
Mean	0.5	-0.4	1.0	0.7	-1.0	-0.6	-0.7	-1.0	0.3	-0.5	-1.7

Figure 2: Most to Least Improved Energy Security Rankings, Based on 1970-2007 Trends

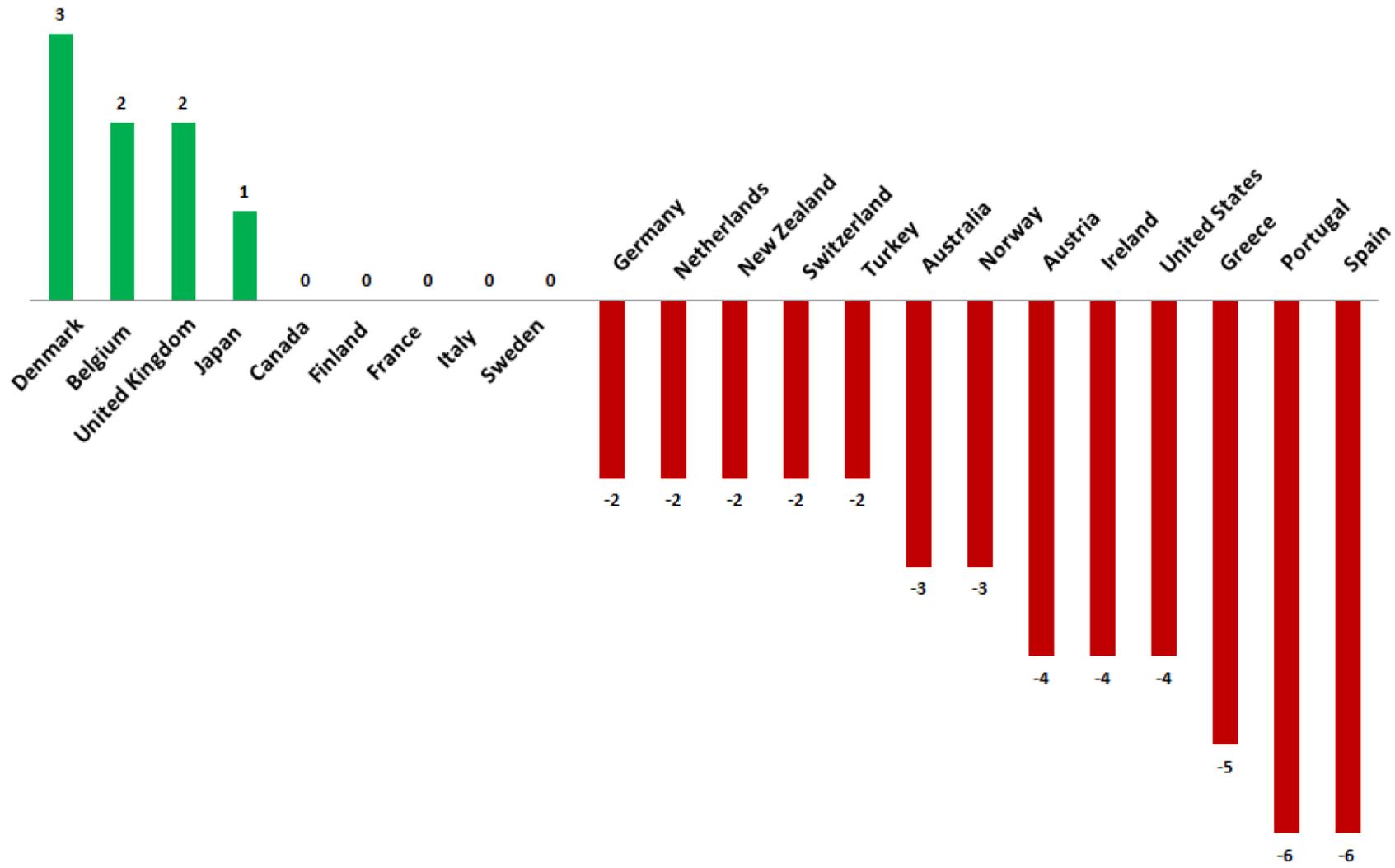
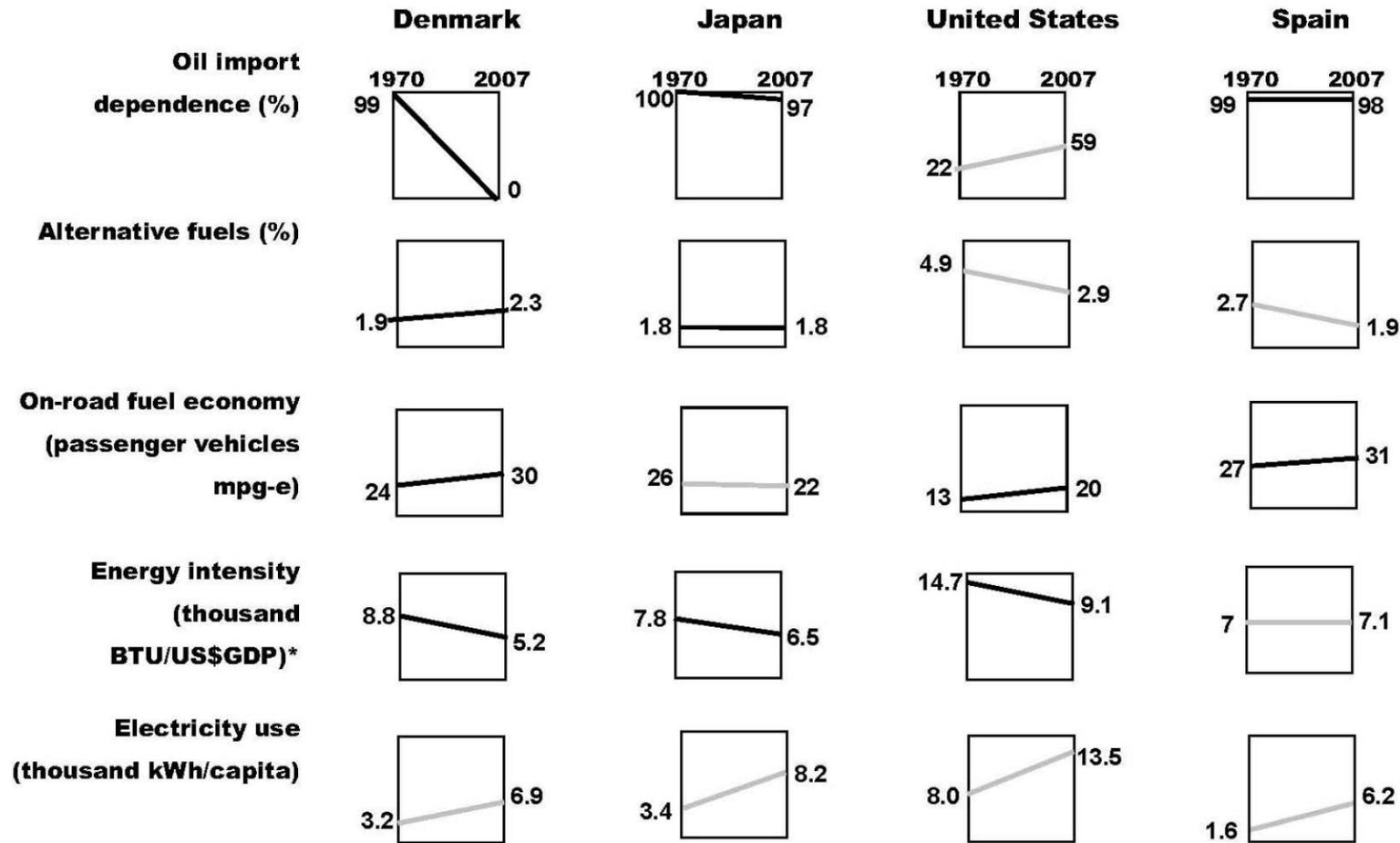
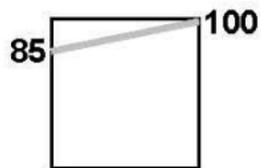
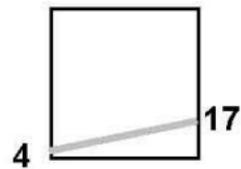
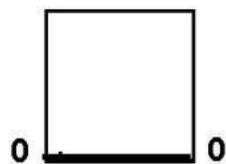


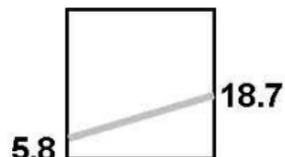
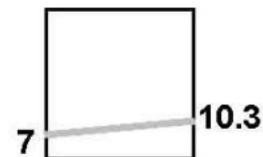
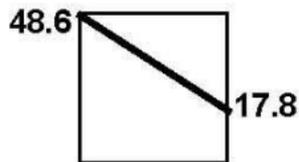
Figure 2: Energy Security Progress for Denmark, Japan, United States, and Spain, 1970 to 2007*



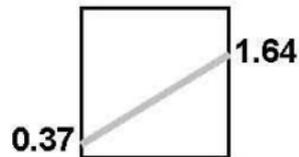
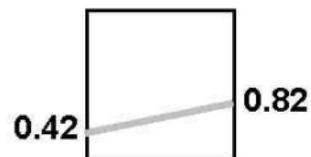
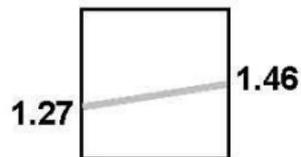
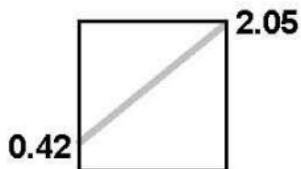
**Natural gas import
dependence (%)**



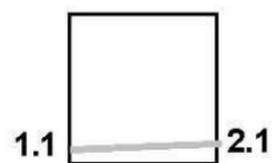
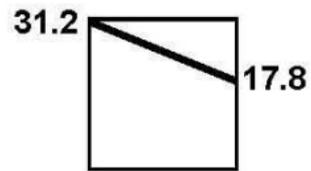
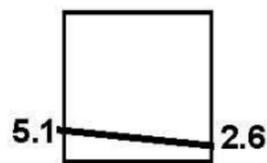
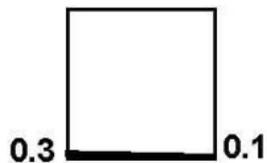
**Nominal electricity
retail prices
(US¢/kWh)**



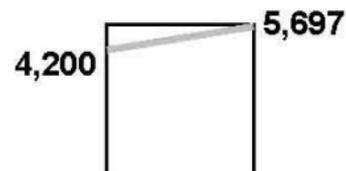
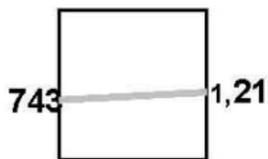
**Nominal gasoline
prices (US\$/liter)**



**SO2 emissions
(million tons)**

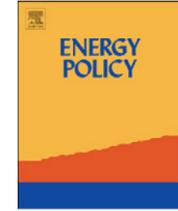


**CO2 emissions
(million tons)**



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Energy policy and cooperation in Southeast Asia: The history, challenges, and implications of the trans-ASEAN gas pipeline (TAGP) network

Benjamin K. Sovacool*

Energy Governance Program, Centre on Asia and Globalisation, Lee Kuan Yew School of Public Policy, National University of Singapore, Singapore

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ABSTRACT

This article explores the proposed multibillion dollar **Trans-ASEAN Gas Pipeline (TAGP)** network in **Southeast Asia**, focusing on the interests that have promoted the TAGP and why. Based on extensive **field research, textual analysis of government reports**, and more than **100 research interviews at government institutions, multilateral development banks, universities, consulting firms, energy companies, and nongovernmental organizations**, this article assesses the challenges facing the TAGP in terms of promotion, implementation, and operation. It explores the genesis of the TAGP project and the drivers pushing Southeast Asian investment in natural gas, with a special emphasis on the development needs of the region. It also investigates the numerous **technical, economic, legal, political, social, and environmental impediments** to the TAGP project. The article concludes that the **rhetoric of regional energy cooperation** touted by the Association of Southeast Asian Nations (ASEAN) **does not match its actual practice**, and that in many cases discussions of **regionalism** and energy security are intended to obscure **opportunistic thinking** within individual countries.

A B S T R A C T

This article explores the proposed multibillion dollar **Trans-ASEAN Gas Pipeline (TAGP)** network in **Southeast Asia**, focusing on the interests that have promoted the TAGP and why. Based on extensive **field research**, **textual analysis of government reports**, and more than **100 research interviews** at **government institutions**, **multilateral development banks**, **universities**, **consulting firms**, **energy companies**, and **nongovernmental organizations**, this article assesses the challenges facing the TAGP in terms of promotion, implementation, and operation. It explores the genesis of the TAGP project and the drivers pushing Southeast Asian investment in natural gas, with a special emphasis on the development needs of the region. It also investigates the numerous **technical**, **economic**, **legal**, **political**, **social**, and **environmental impediments** to the TAGP project. The article concludes that the **rhetoric of regional energy cooperation** touted by the Association of Southeast Asian Nations (ASEAN) **does not match its actual practice**, and that in many cases discussions of **regionalism** and energy security are intended to obscure **opportunistic thinking** within individual countries.

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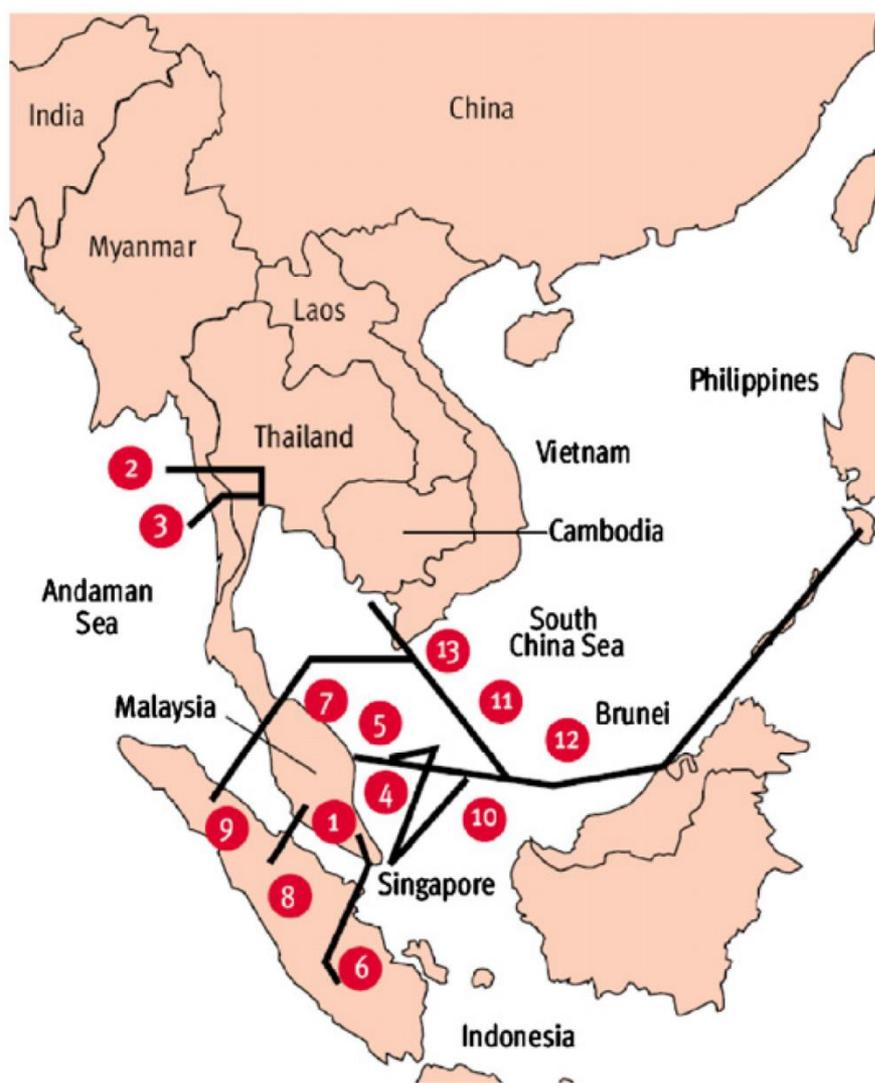


Fig. 2. The Proposed Trans-ASEAN Gas Pipeline (TAGP) Network. *Source:* modified from Peter Roberts and Alex Cull, "Building the Trans-ASEAN Gas Pipeline," *Asia Pacific Review* (July, 2003), pp. 15–20. **Legend:** (1) Malaysia to Singapore, (2) Myanmar (Yadana) to Thailand (Ratchaburi), (3) Myanmar (Yetagun) to Thailand (Ratchaburi), (4) Indonesia (West Natuna) to Singapore, (5) Indonesia (West Natuna) to Malaysia (Duyong), (6) Indonesia (Grissik) to Singapore, (7) Thailand (Joint Development Area) to Malaysia, (8) Indonesia (South Sumatra) to Malaysia, (9) Indonesia (Arun) to Malaysia (commissioning estimated 2010), (10) Indonesia (East Natuna and West Natuna) to Malaysia (Kerteh) and Singapore (commissioning estimated 2010), (11) Indonesia (East Natuna) to Thailand (JDA-Erawan) (commissioning estimated 2012), (12) Indonesia (East Natuna) to Malaysia (Sabah) and the Philippines (Palawan-Luzon) (commissioning estimated 2015), and (13) Malaysia-Thailand (JDA) to Vietnam (Block B) (commissioning estimated 2016).

Table 3

Natural gas reserves in select ASEAN countries (in trillion cubic feet (tcf)).

Country	Proven reserves	Possible reserves	Probable Reserves	Total
Brunei	8	4	0	12
Indonesia	90	42	34	166
Malaysia	58	28	0	86
Philippines	3	1	1	5
Singapore	0	0	0	0
Thailand	12	9	11	32
Vietnam	5	11	9	25
ASEAN	175	94	55	325

Table 5

Primary energy consumption in select ASEAN countries (in MTOE).

Country	1990	1999	2006	% increase
Indonesia	52.3	79.6	114.3	219
Malaysia	21.5	38.0	67.0	312
Philippines	13.0	21.6	25.2	194
Singapore	20.3	29.6	50.0	246
Thailand	28.8	59.3	86.1	299
Total	135.9	228.1	342.6	252

Table 4
The challenges and impediments to the TAGP network.

Technical	Economic	Legal	Political	Social	Environmental
Pipeline construction and operation	Uncertainty surrounding gas reserves	Inconsistent regulatory frameworks	Contests over sovereignty	Poor participatory mechanisms	Land degradation
	Unknown future demand for gas	Unclear protection of property rights	Diplomatic tensions	Lack of transparency	Accidents and spills
	Capital intensity	State control of markets	Protectionism	Relocation, resettlement, and human rights concerns	Greenhouse gas emissions and climate change
	Financing	Weak mechanisms for dispute settlement	Lack of sustained leadership		
	Returns on investment	Setting acceptable gas prices and tariffs			

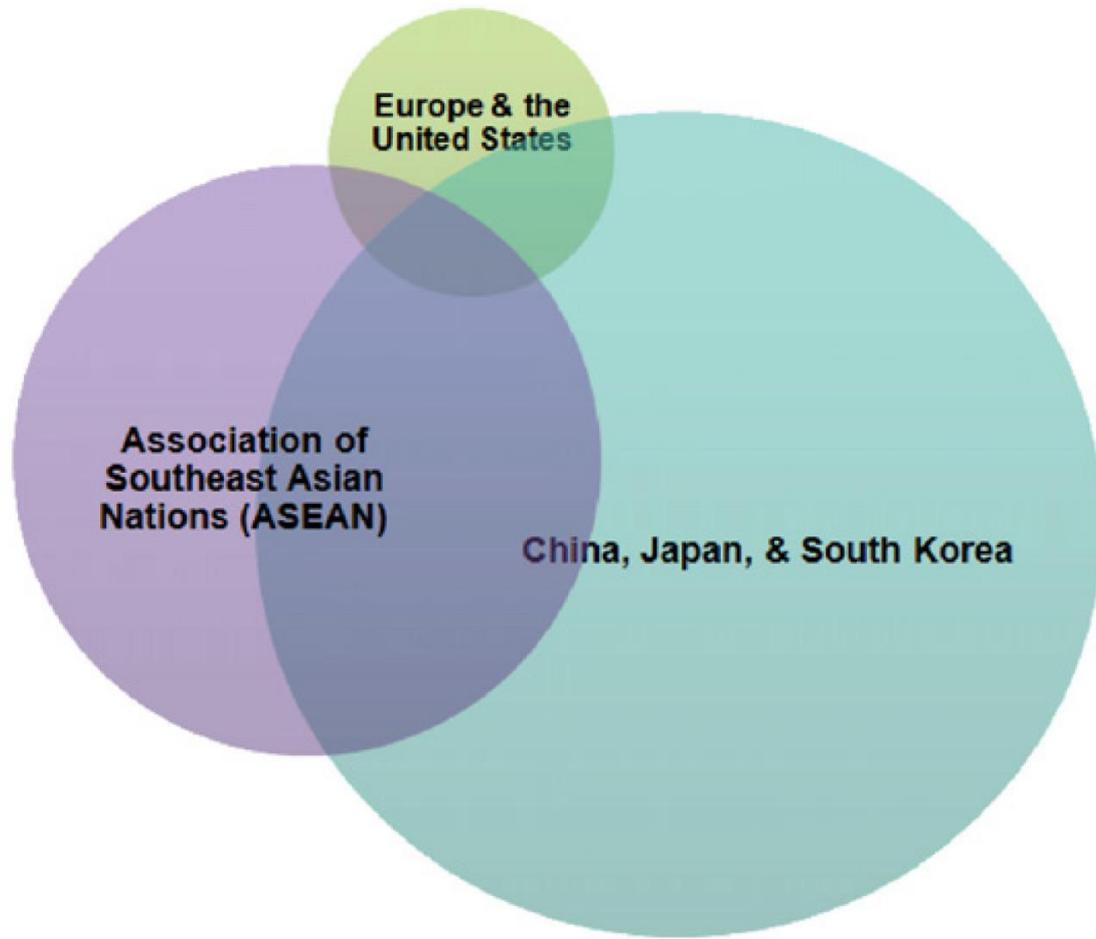


Fig. 3. The three spheres of suspicion and influence between ASEAN, regional powers, and western powers.

Snakes in the Grass: The Energy Security Implications of Medupi

The proposed 4,800 MW coal-fired power plant Medupi in South Africa demonstrates how different aspects of energy security can conflict with each other.

Benjamin K. Sovacool and William Rafey

Benjamin K. Sovacool is an Assistant Professor at the Lee Kuan Yew School of Public Policy, part of the National University of Singapore. He is also a Research Fellow in the Energy Governance Program at the Centre on Asia and Globalization. He can be contacted via email at bsovacool@nus.edu.sg.

William Rafey is studying social studies at Harvard College and is particularly interested in global environmental change and sustainable development. He can be contacted at rafey@college.harvard.edu.

Table 1: Four Components of Energy Security.

Component	Explanation
Availability	Diversifying the fuels used to provide energy services as well as the location of facilities using those fuels, promoting energy systems that can recover quickly from attack or disruption, and minimizing dependence on foreign suppliers
Affordability	Providing energy services that are affordable for consumers and minimizing price volatility
Efficiency and development	Improving the performance of energy equipment, altering consumer attitudes, and developing a robust energy infrastructure to widely distribute energy services
Environmental and social stewardship	Protecting the natural environment, communities and future generations

*The most vehement
debate over
the project
surrounded
the World Bank's
April 8, 2010,
final decision
about its loan.*

Instead of investing in this non-depletable, arguably less capital-intensive, and more equitable technology, the government instead chose to erect a single centralized plant.

*We see renewable
energy, not
coal-fired power
stations, as
the optimal
development
path for Southern
economies.*

Table 2: Overview of Medupi’s Energy Security Implications.

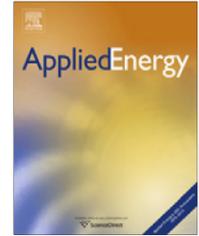
Dimension of Energy Security	Positive Impacts	Negative Impacts
Availability	Enhancing security of supply, expanding energy infrastructure, and preventing electricity blackouts	
Affordability	Improved reliability of electricity supply for all households	Electricity rate hikes that could hurt the poor, decreased motivation to invest in renewables and green jobs
Efficiency and development	Continued economic growth, strengthened minerals and mining enterprises, and improved national competitiveness	Widening of the rich-poor gap, support of an export-oriented economy that may exacerbate social inequality and perpetuate the “resource curse”
Environmental and social stewardship	Relies on supercritical components that are hyper-efficient, supports renewable energy as part of the World Bank loan, and enables the government to follow through on future climate-change plans	Emits significant amounts of greenhouse gases, contributes to environmental degradation associated with coal combustion and mining, and “locks in” coal

11. For a small sample of these studies, see Anna Pegels, *Renewable Energy in South Africa: Potentials, Barriers and Options for Support*, ENERGY POLICY, Vol. 38, Issue 9, Sept. 2010, at 4945-4954; Harald Winkler, *Renewable Energy Policy in South Africa: Policy Options for Renewable Electricity*, ENERGY POLICY, Vol. 33, Issue 1, Jan. 2005, at 27-38; and I.M. Bugaje, *Renewable Energy for Sustainable Development in Africa: A Review*, RENEWABLE & SUSTAINABLE ENERGY REV., Vol. 10, Issue 6, Dec. 2006, at 603-612.



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China's energy security: The perspective of energy users

Malavika Jain Bambawale*, Benjamin K. Sovacool

Energy Governance Program, Centre on Asia and Globalisation, Lee Kuan Yew School of Public Policy, National University of Singapore, Oei Tiong Ham Building, 469C Bukit Timah Road, Singapore 259772, Singapore

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ABSTRACT

The article explores the **energy security concerns** faced by **China** from the point of view of **energy users** working in **government, university, civil society** and **business** sectors. The authors first derive a set of **seven hypotheses** related to Chinese energy security drawn from a review of the recent academic literature. We then explain each of these seven hypotheses, relating to (1) **security of energy supply**, (2) **geopolitics**, (3) **climate change**, (4) **decentralization**, (5) **energy efficiency**, (6) **research** and **innovation** of new energy technologies, and (7) **self sufficiency** and **trade**. Lastly, the article tests these hypotheses through a **survey** distributed in English and Mandarin completed by **312 Chinese participants**. The conclusion presents insights for policymakers and energy scholars.

A B S T R A C T

The article explores the energy security concerns faced by China from the point of view of energy users working in government, university, civil society and business sectors. The authors first derive a set of seven hypotheses related to Chinese energy security drawn from a review of the recent academic literature. We then explain each of these seven hypotheses, relating to (1) security of energy supply, (2) geopolitics, (3) climate change, (4) decentralization, (5) energy efficiency, (6) research and innovation of new energy technologies, and (7) self sufficiency and trade. Lastly, the article tests these hypotheses through a survey distributed in English and Mandarin completed by 312 Chinese participants. The conclusion presents insights for policymakers and energy scholars.

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3.1. H1: One would expect a country such as China to be predominantly concerned about the security of fossil fuel supply, given its rapid economic growth

3.2. H2: Energy trade is unlikely to be a key dimension of energy security, given that China has placed emphasis on self dependence and has a “going out” strategy to make investments and acquisitions abroad

3.3. H3: Although traditionally, China has focused on economic growth, one would expect that growing environmental concerns from national and international sources would make climate change a salient issue

3.4. H4: Decentralized systems would not be important for a country like China, because of its tradition of central planning and the centralized nature of its current energy decision making and execution

3.5. H5: Energy efficiency would be of high importance, especially among those working in the manufacturing sector, because China has the goal of increasing GDP without a substantial rise in energy consumption

3.6. H6: Renewable energy and R&D would be highly important for China's policymakers, given China's increasingly important status in the world as a renewable energy leader and the potential for renewable energy to solve its energy shortage

3.7. H7: One would expect a country such as China to place emphasis on military and geopolitical security given that its energy demand is likely to lead to conflicts of interest with other large energy consuming nations

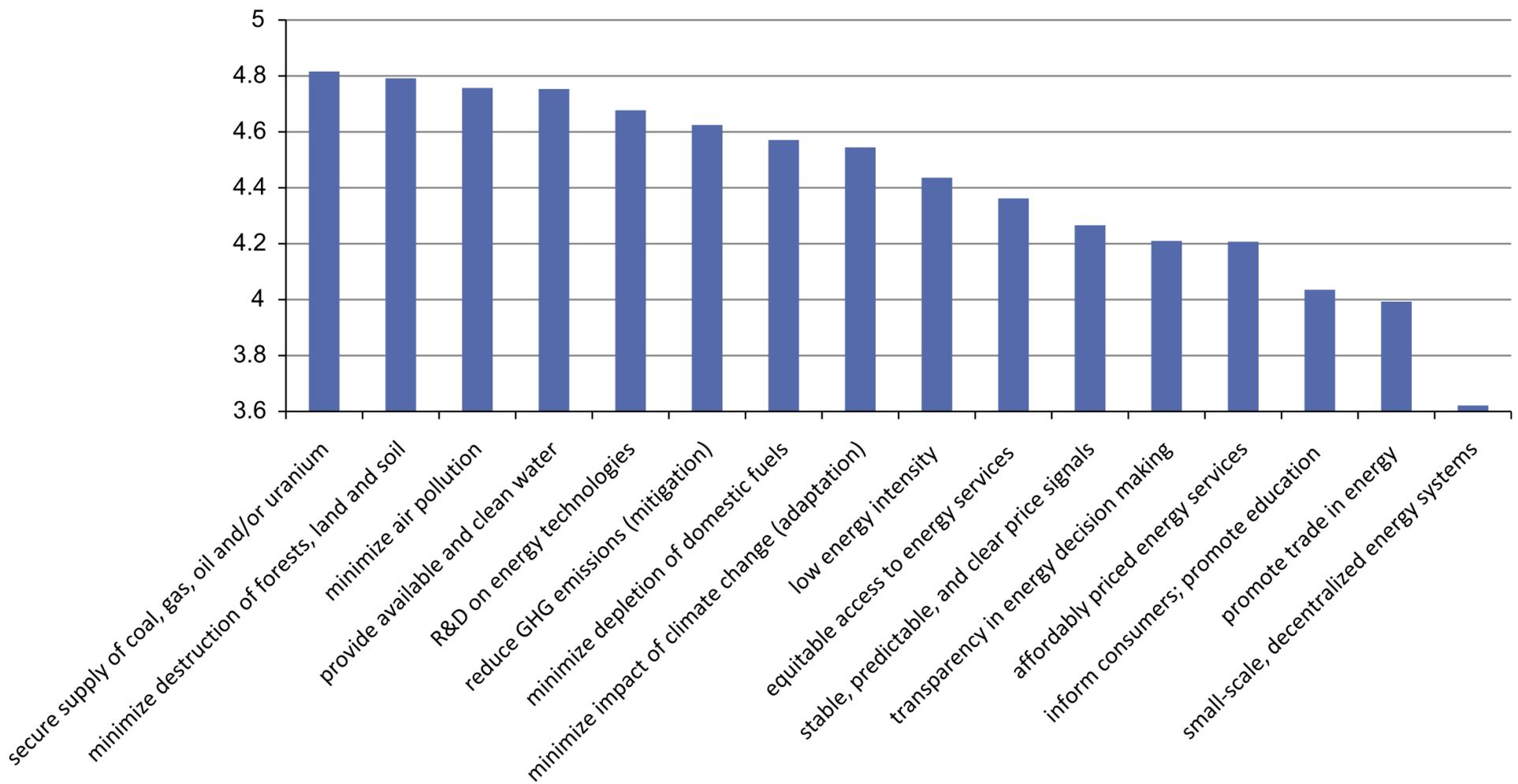


Fig. 2. Average rating given to the dimension based on an importance scale from 1 to 5. (5=extremely important, 1 = extremely unimportant).

Table 1
Ratings to energy security dimensions by different occupation categories.

Dimension	Government	Non profit	Private sector	University
secure supply of coal, gas, oil and/or uranium	4.90	4.71	4.70	4.83
promote trade in energy products, technologies, and exports	4.12	3.86	3.91	3.96
minimize depletion of domestically available energy fuels	4.54	4.71	4.62	4.62
stable, predictable, and clear price signals	4.39	4.43	4.19	4.21
affordably priced energy services	4.22	4.29	4.24	4.18
small-scale, decentralized energy systems	3.71	3.86	3.57	3.54
low energy intensity (unit of energy required per unit of economic output)	4.48	4.57	4.36	4.46
R&D on new and innovative energy technologies	4.74	4.57	4.64	4.71
equitable access to energy services to all of its citizens	4.47	4.14	4.38	4.29
transparency and participation in energy permitting, citing, and decision-making	4.24	4.57	4.26	4.12
inform consumers and promote education about energy issues	4.02	3.57	3.94	4.14
minimize the destruction of forests and the degradation of land and soil	4.73	4.71	4.90	4.79
provide available and clean water	4.64	4.86	4.78	4.82
minimize air pollution	4.65	4.86	4.86	4.77
minimize the impact of climate change (i.e., adaptation)	4.55	4.57	4.46	4.59
reduce greenhouse gas emissions (i.e. mitigation)	4.54	4.71	4.64	4.69

Note: (1) Green stands for high ratings, yellow for medium and red for low ratings. (2) Data for Intergovernmental sector is not shown because of its small sample size.

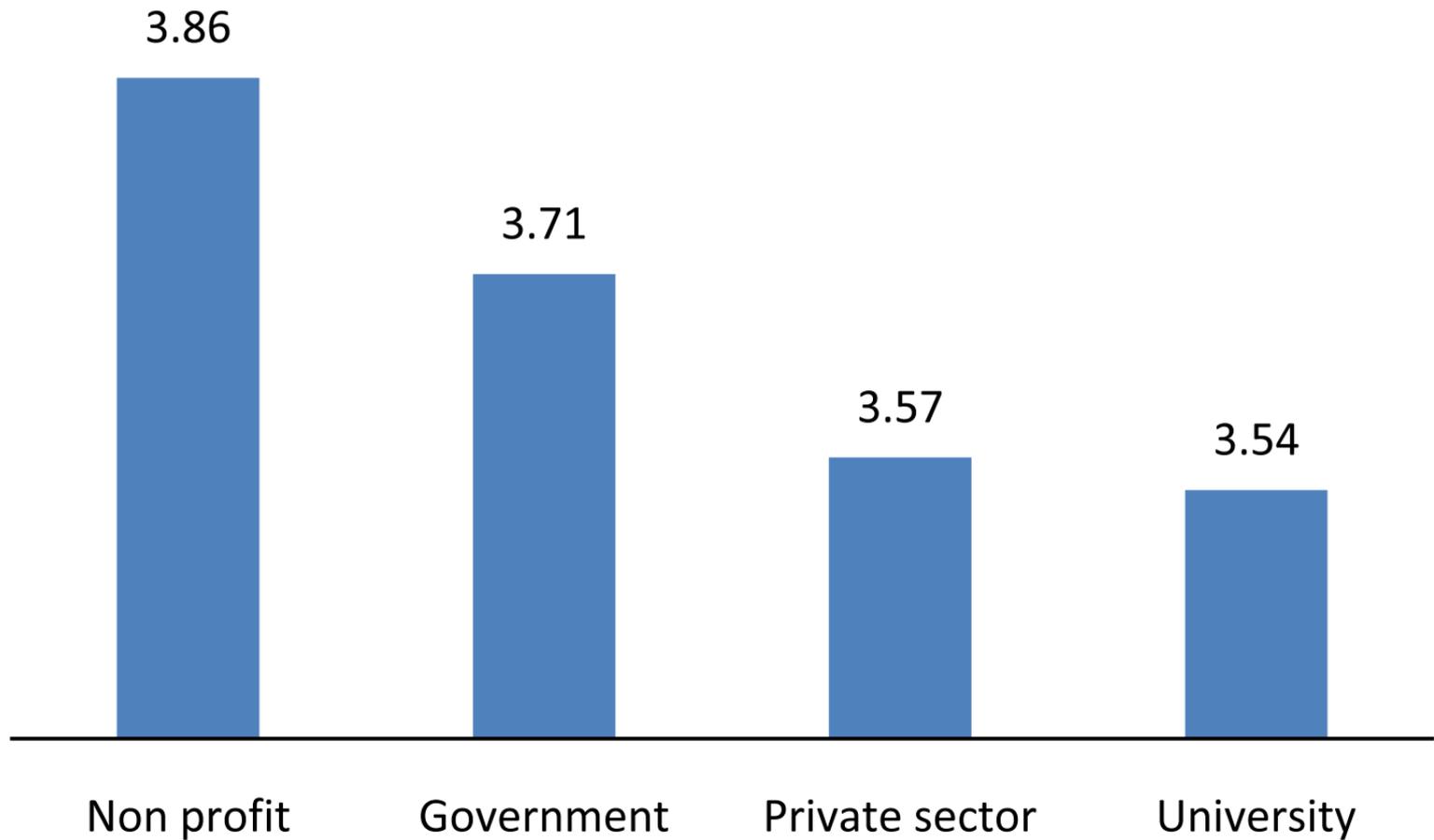


Fig. 4. Ratings for “decentralized small scale systems” broken down by occupation categories of respondents.

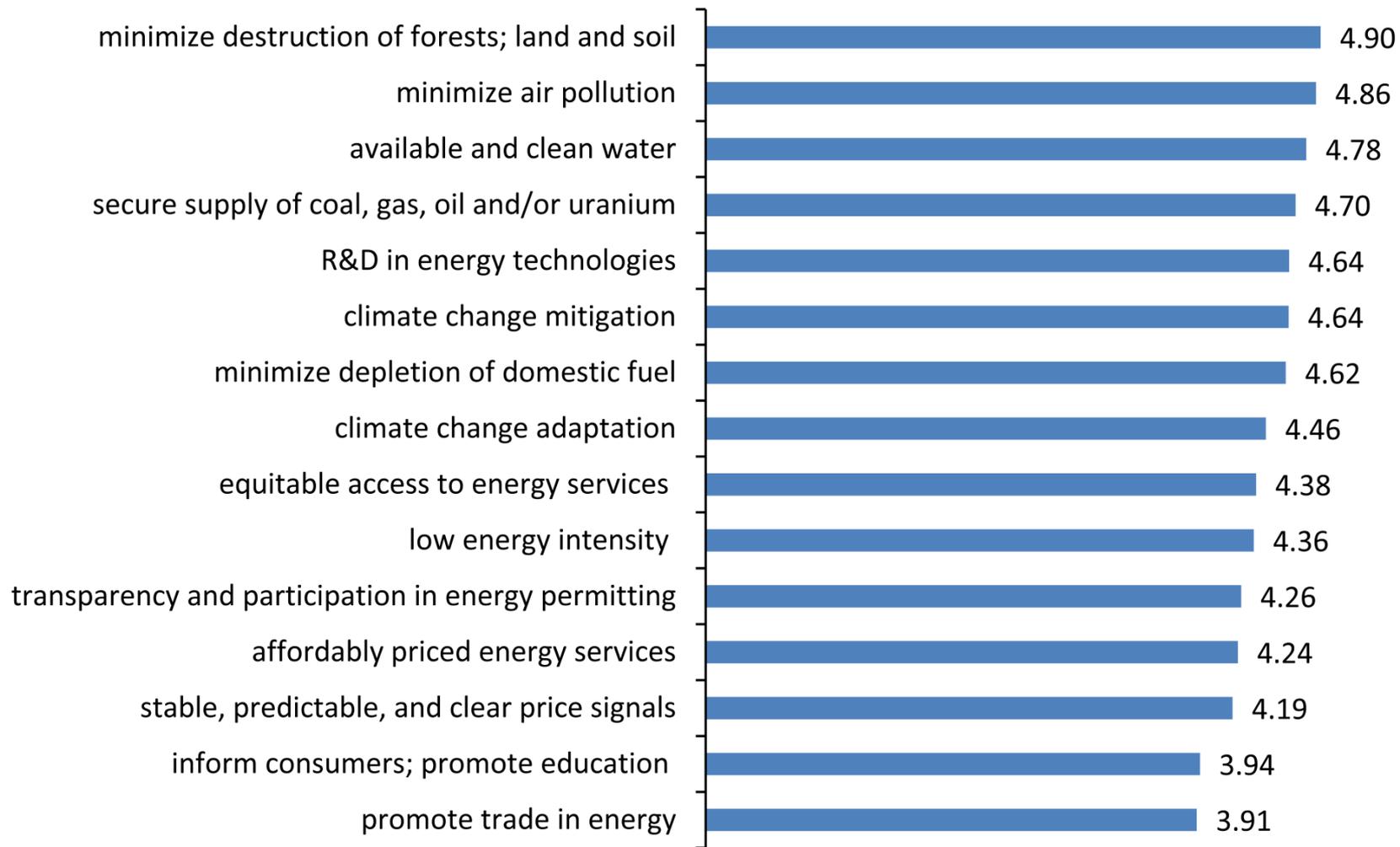


Fig. 3. The private sector's ratings of 16 dimensions.

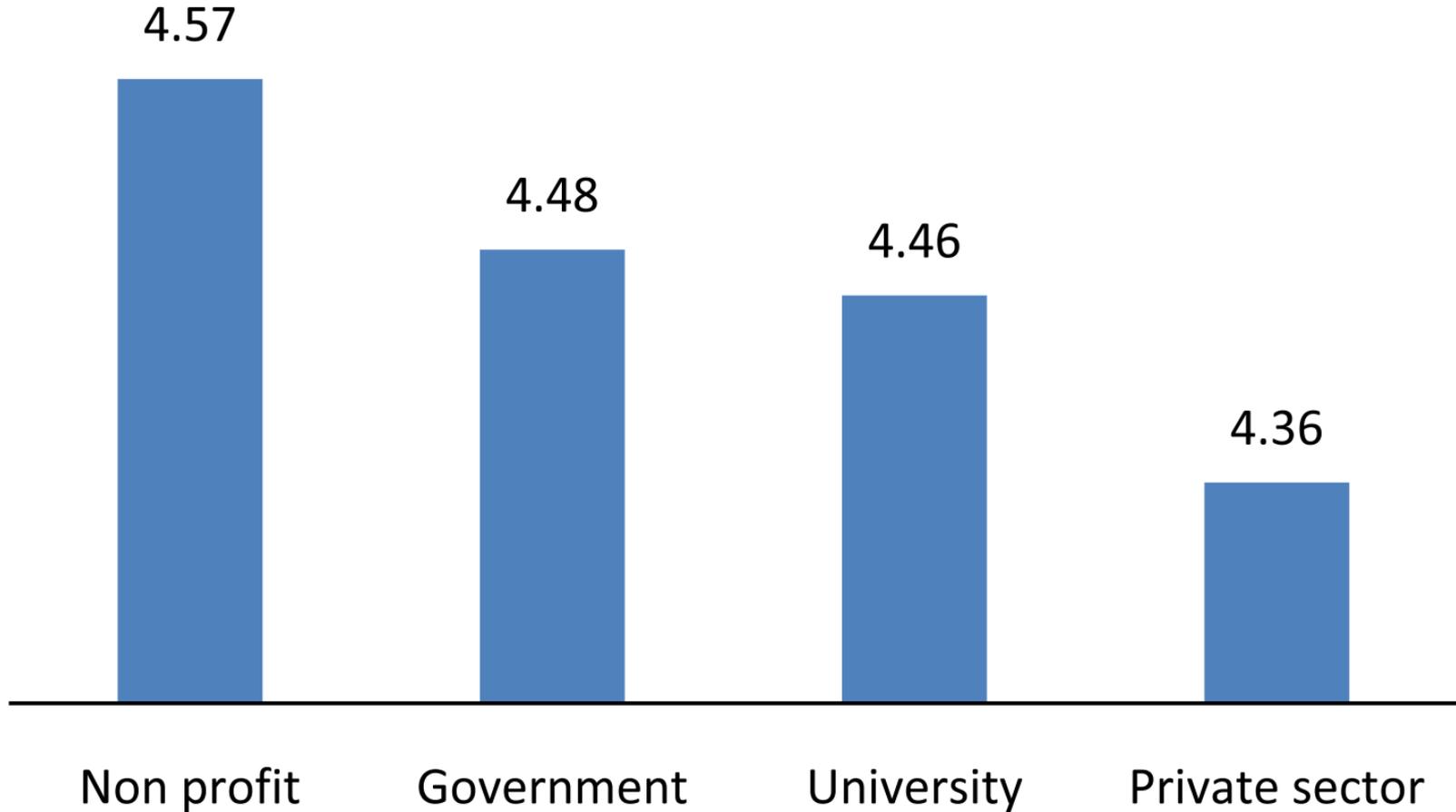


Fig. 5. Ratings for “low energy intensity (unit of energy required per unit of economic output)” by respondents in different occupation categories.

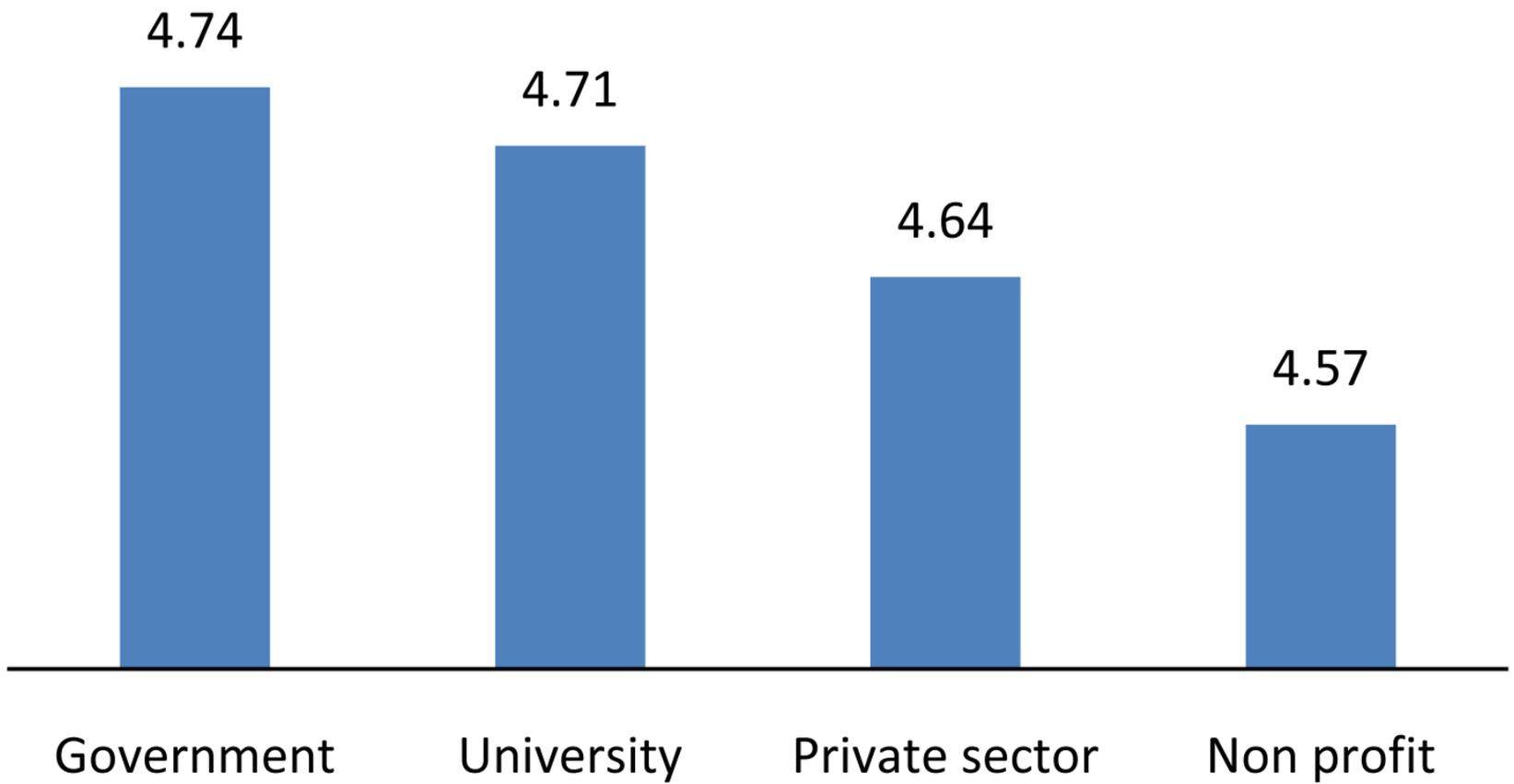


Fig. 6. Ratings for “R&D in new and innovative energy technologies” by respondents in different occupation categories.

Since we did not have a direct question in the survey about geopolitics, we inferred its importance in three ways – answers to the question about trade in energy products, answers about the security of supply of fossil fuels, and the open-ended question at the end of the survey.

Thus, two of the three proxies for geopolitics suggest it is of moderate importance.



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Conceptualizing and measuring energy security: A synthesized approach

Benjamin K. Sovacool*, Ishani Mukherjee

Lee Kuan Yew School of Public Policy, National University of Singapore, 469C Bukit Timah Road, 259772 Singapore, Singapore

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ABSTRACT

This article provides a synthesized, workable framework for analyzing national energy security policies and performance. Drawn from research **interviews**, **survey** results, a focused **workshop**, and an extensive **literature review**, this article proposes that energy security ought to be comprised of **five dimensions** related to **availability**, **affordability**, **technology development**, **sustainability**, and **regulation**. We then break these five dimensions down into **20 components** related to security of supply and production, dependency, and diversification for availability; price stability, access and equity, decentralization, and low prices for affordability; innovation and research, safety and reliability, resilience, energy efficiency, and investment for technology development; land use, water, climate change, and air pollution for sustainability; and governance, trade, competition, and knowledge for sound regulation. Further still, our synthesis lists **320 simple indicators** and **52 complex indicators** that policymakers and scholars can use to analyze, measure, track, and compare national performance on energy security. The article concludes by offering implications for energy policy more broadly.

A B S T R A C T

This article provides a synthesized, workable framework for analyzing national energy security policies and performance. Drawn from research **interviews**, **survey** results, a focused **workshop**, and an extensive **literature review**, this article proposes that energy security ought to be comprised of **five dimensions** related to **availability**, **affordability**, **technology development**, **sustainability**, and **regulation**. We then break these five dimensions down into **20 components** related to security of supply and production, dependency, and diversification for availability; price stability, access and equity, decentralization, and low prices for affordability; innovation and research, safety and reliability, resilience, energy efficiency, and investment for technology development; land use, water, climate change, and air pollution for sustainability; and governance, trade, competition, and knowledge for sound regulation. Further still, our synthesis lists **320 simple indicators** and **52 complex indicators** that policymakers and scholars can use to analyze, measure, track, and compare national performance on energy security. The article concludes by offering implications for energy policy more broadly.

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We began by conducting semi-structured research interviews with global energy security experts using a “modified Delphi method” [5,6] that involved asking key scholars a series of open ended questions. The lead author conducted 68 semi-structured research interviews over the course of February 2009 to November 2010, including visits to the International Energy Agency, U.S. Department of Energy, United Nations Environment Program, Energy Information Administration, World Bank Group, Nuclear Energy Agency, and International Atomic Energy Agency. Participants at these institutions were asked three questions:

1. Which dimensions of energy security are most important?
2. What metrics best capture these dimensions?
3. How might these metrics be used to create a common index or scorecard to measure national performance on energy security?⁶⁹

Table 1
Energy security dimensions, values, and components.

Dimension	Explanation	Underlying Values	Components
Availability	Having sufficient supplies of energy. Being energy independent. Promoting a diversified collection of different energy technologies. Harnessing domestically available fuels and energy resources. Ensuring prudent reserve to production ratios	Self sufficiency, resource availability, security of supply, independence, imports, variety, balance, disparity	Security of Supply and Production Dependency Diversification
Affordability	Producing energy services at the lowest cost, having predictable prices for energy fuels and services, and enabling equitable access to energy services.	Cost, stability, predictability, equity, justice, reducing energy poverty	Price Stability Access and Equity Decentralization Affordability
Technology Development and Efficiency	Capacity to adapt and respond to the challenges from disruptions, researching and developing new and innovative energy technologies, making proper investments in infrastructure and maintenance. Delivering high quality and reliable energy services.	Investment, employment, technology development and diffusion, energy efficiency, stockholding, safety and quality	Innovation and Research Safety and Reliability Resilience Efficiency and Energy Intensity Investment and Employment
Environmental and Social Sustainability	Minimizing deforestation and land degradation, possessing sufficient quantity and suitable quality of water, minimizing ambient and indoor pollution, mitigating GHG emissions associated with climate change, adapting to climate change.	Stewardship, aesthetics, natural habitat conservation, water quality and availability, human health, climate change mitigation, climate change adaptation.	Land Use Water Climate Change Pollution
Regulation and Governance	Having stable, transparent, and participatory modes of energy policymaking, competitive markets, promoting trade of energy technology and fuels, enhancing social and community knowledge about education and energy issues	Transparency, accountability, legitimacy, integrity, stability, resource curse, geopolitics, free trade, competition, profitability, interconnectedness, security of demand, exports	Governance Trade and Regional Interconnectivity Competition and markets Knowledge and Access to Information

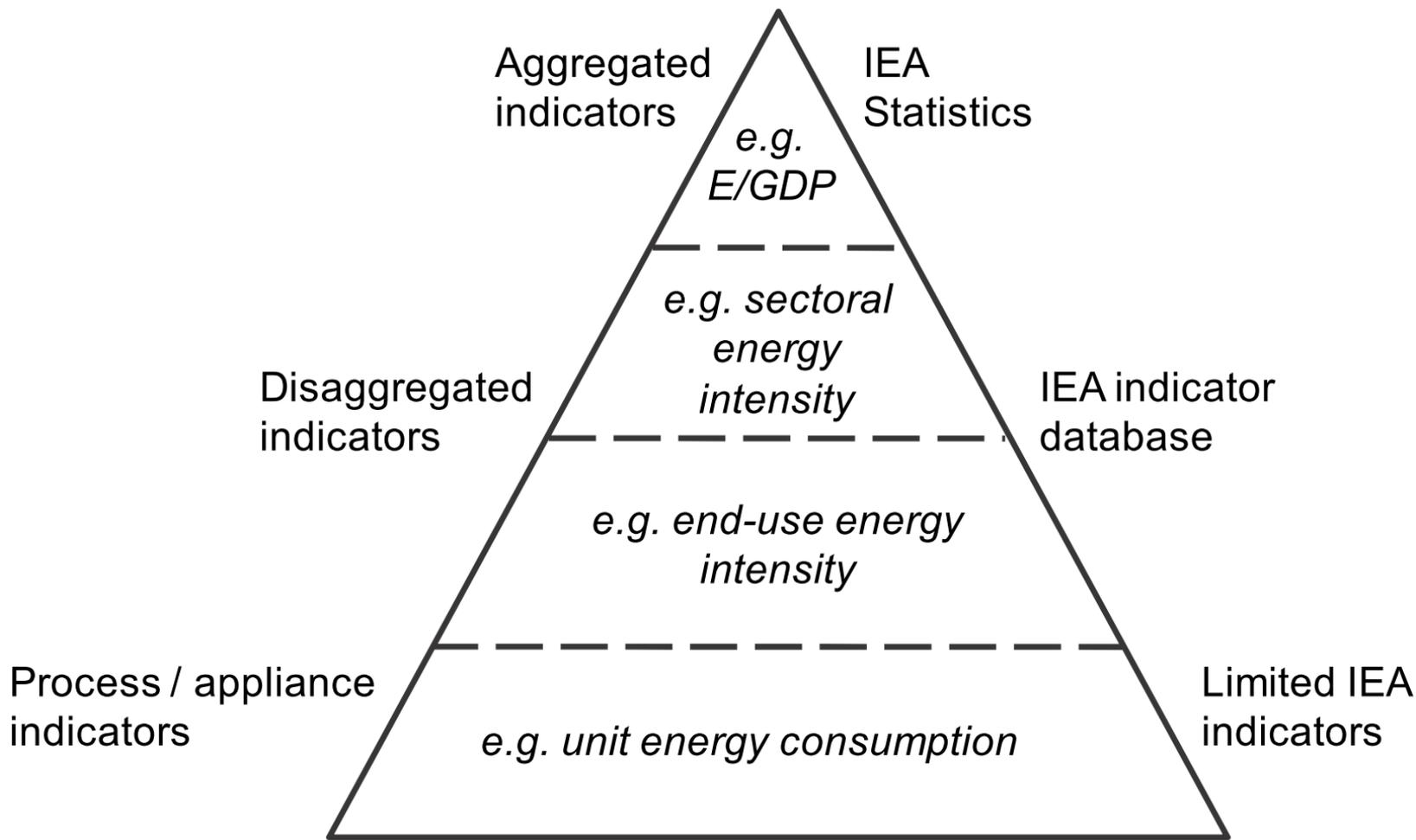


Fig. 2. The International Energy Agency “Pyramid” of Energy Indicators.

Table 2
Simple, Intermediate, and Complex Indicators for Energy Security.

Aspect of Energy Security	Quantity (Simple)	Quality (Intermediate)	Context (Complex)
Energy Imports	Share of imported energy in total energy balance, or made more specific by type of fuel (e.g., oil, coal, natural gas, uranium)	Nature of energy imports (type of imported energy and mode of import)	Specific context of energy imports for particular country or community
Energy Production and Infrastructure	Diversity of primary energy supply in domestic production	Domestic energy resources, reserve-to-production ratios	Country specific energy production and infrastructure challenges
Energy Production and Infrastructure	National power generation capacity (total or per capita)	Domestic energy infrastructure investments	Mitigation readiness and capacity
Vulnerability to Disruption	Energy consumption per capita	Costs of imports versus export earnings	Sectoral vulnerability for transport, residential, industry, tertiary, agriculture
Vulnerability to Disruption	Energy intensity of GDP	GDP intensity by type of energy or sector	
Vulnerability to Disruption	Fuel Economy	Fuel economy for on-road passenger vehicles, or new vehicles	
Equity and Access to Energy Services	Percentage of households with a reliable connection to the electricity grid	Share of household income spent on energy services	GINI coefficient of energy use
Diversification	Renewable share of energy fuel mix	Diversify of primary energy supply	Hirshman and Shannon indices of diversity
Greenhouse Gas Emissions	Total greenhouse gas emissions or per capita greenhouse gas emissions	Greenhouse gas emissions by sector	Carbon dioxide intensity of specific energy carriers

Dimensions and components of Energy Security:

☐ **Availability**

- ✓ Security of supply & production
- ✓ Dependency
- ✓ Diversification

☐ **Affordability**

- ✓ Price stability
- ✓ Access & equity
- ✓ Decentralization
- ✓ Affordability

Dimensions and components of Energy Security:

☐ **Technology development & efficiency**

- ✓ Innovation & research
- ✓ Safety & reliability
- ✓ Resilience & adaptive capacity
- ✓ Efficiency & energy intensity
- ✓ Investment & employment

Dimensions and components of Energy Security:

Environmental & social sustainability

- ✓ Land use
- ✓ Water
- ✓ Climate change
- ✓ Pollution

Dimensions and components of Energy Security:

□ **Regulation & governance**

- ✓ Governance
- ✓ Trade & regional interconnectivity
- ✓ Competition & markets
- ✓ Knowledge & access to information

of studies, the following types of indicators would be classified as “simple”:

- Resource estimates and reserves;
- Reserve to production ratios;
- Share of zero-carbon fuels;
- Import dependence;
- Political risk rating;
- Energy prices;
- Ratio of a country’s consumption over the total market for a fuel;
- Energy intensity;
- Energy expenditures for research.

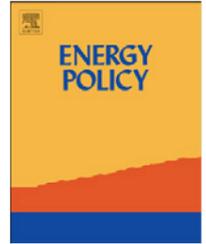


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Forum

Evaluating energy security in the Asia pacific: Towards a more comprehensive approach

Benjamin K. Sovacool*

Lee Kuan Yew School of Public Policy, National University of Singapore, 469C Bukit Timah Road 259772, Singapore

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ABSTRACT

The **energy security conundrum** – how to equitably provide **available, affordable, reliable, efficient**, and **environmentally benign** energy services – is a **technology and policy challenge**, perhaps unlike any other. The **recent article on an energy security in the Asia Pacific by Vlado Vivoda** is an excellent starting point for how to best capture the **unique energy security challenges facing the region**. This article builds on Vivoda's work, but also points out some shortcomings with his analysis.

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A B S T R A C T

The **energy security conundrum** – how to equitably provide **available, affordable, reliable, efficient,** and **environmentally benign** energy services – is a **technology and policy challenge**, perhaps unlike any other. The **recent article on an energy security in the Asia Pacific by Vlado Vivoda** is an excellent starting point for how to best capture the **unique energy security challenges facing the region**. This article builds on Vivoda's work, but also points out some shortcomings with his analysis.

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Vlado Vivoda's (2010) recent article on energy security in the Asia Pacific is a pleasure to read. It provides a much needed overview of the energy security challenges facing the region and also develops an energy security assessment instrument, including 11 broad dimensions and 44 attributes that can be utilized to evaluate national performance on energy issues. His study shows quite nicely how energy security cuts across different areas, involving:

- Geological aspects such as resource reserves and the availability of energy technologies and fuels;
- Economic aspects like trade, production of resources, price stability, and affordability;
- Socio-political aspects like governance, resilience, and the ability to cope with climate change;
- Environmental aspects such as insults to land, air, and water.

To ensure a relatively representative sample of Asian experts, the author also approached participants working at:

- Universities such as Chiang Mai University in Thailand and the University of Tokyo in Japan;
- Government organizations such as the Chinese Academy of Sciences and the Malaysia Energy Centre;
- Civil society groups and nongovernmental organizations, such as the Asia Pacific Energy Research Centre or The Energy and Resources Institute in India;
- Intergovernmental organizations such as the United Nations Environment Program and Association of Southeast Asian Nations.

strategic reasons”. [Keppler \(2007\)](#) has noted, for example, that energy unavailability can occur for a variety of reasons, including:

- Embargoes or the exercise of monopoly power by a single actor or cartel (such as an OPEC);
- Internal problems with suppliers such as civil war, political tension, or strikes (such as the famous coalminers strike in the United Kingdom);
- Limitations of capacity due to lack of investment, bad management, or lack of foreign direct investment (Asian financial crisis of the late 1990s);
- Political crises (such as the Suez Canal);
- Commercial disputes (think natural gas and Ukraine and Russia);
- Sabotage (such as attacks on Iraqi oil pipelines);
- Extreme weather events (such as Hurricane Katrina);
- Technical accidents (such as the famous 2003 blackout in North America);
- Inadequate capacity (such as the California energy crisis).

Table 1
Energy security dimensions identified by experts.

Dimension	Explanation	Underlying values
Availability	Having sufficient supplies of energy	Self sufficiency, resource availability
Dependency	Being energy independent	Security of supply, independence, imports
Diversification	Promoting a diversified and decentralized collection of different energy technologies	Variety, balance, disparity
Decentralization	Reliance on small-scale sources of energy supply near the point of consumption	Modularity, comprehensibility, physical security
Innovation	Researching and developing new and innovative energy technologies	Development, diffusion
Investment	Making proper investments in infrastructure and maintenance	Investment, employment
Trade	Promoting the trade of energy technologies and fuels	Geopolitics, free trade, transport routes, interconnectedness, security of demand, exports
Production	Producing domestically available fuels and energy resources	Economic growth, reliability
Price stability	Having predictable prices for energy fuels and services	Clarity, predictability
Affordability	Producing energy services at the lowest cost	Competition, subsidization, profitability
Governance	Having stable, transparent, and participatory modes of energy policymaking and permitting	Transparency, accountability, legitimacy, integrity, stability, resource curse
Access	Enabling equitable access to energy services	Energy poverty, equity
Reliability	Delivering high quality and reliable energy services	Safety, quality, accidents
Literacy	Social and community knowledge and education about energy issues	Knowledge, accuracy, information, feedback, internalization of externalities
Resilience	Capacity to adapt and respond to the challenges induced by climate change or disruptions in supply	Adaptation, stockpiling, stockholding
Land use	Minimizing destruction of forests and degradation of land	Stewardship, aesthetics
Water	Possessing sufficient quantities of water	Water quality, water availability
Pollution	Minimizing ambient and indoor levels of air pollution	Human health
Efficiency	Producing energy in the most efficient manner possible	Conservation, energy efficiency
Greenhouse gas emissions	Mitigating greenhouse gas emissions associated with climate change	Mitigation

Access centered on equity and fairness in acquiring energy services. One respondent explained it this way:

The stability or affordability of energy prices is just one component of energy poverty. Often missed are access and equity. Poverty and development is not just about how one lives, but their potential, how they can escape poverty in the future. This means energy services should not only have predictable prices at the lowest cost, but also be fairly distributed to all members of the society.

Table 2
 Energy related environmental damages in developing countries.
 Source: Holdren and Smith, 2000: 64.

Environmental damage	Human disruption index	Tons emitted/discharged per year	% Related to commercial energy supply	% Related to traditional energy supply	% Related to agriculture	% Related to manufacturing/other
Lead emissions to the atmosphere	18	12,000	41% (Fossil fuel burning)	Negligible	Negligible	59% (Metal processing, manufacturing, waste incineration)
Oil added to the oceans	10	200,000	44% (Petroleum production, processing, and transport)	Negligible	Negligible	56% (Disposal of oil wastes)
Cadmium emissions to the atmosphere	5.4	1400	13% (Fossil fuel combustion)	5% (Traditional fuel burning)	12% (Agricultural burning)	70% (Metals processing, manufacturing, waste incineration)
Sulfur emissions to the atmosphere	2.7	31,000,000	85% (Fossil fuel combustion)	0.5% (Traditional fuel burning)	1% (Agricultural burning)	13% (Smelting, waste incineration)
Methane emissions	2.3	160,000,000	18% (Fossil fuel harvesting, processing, combustion)	5% (Traditional fuel burning)	65% (Rice paddy conversion, livestock production, land clearing)	12% (Landfills)

Nitrogen fixation (as nitrogen oxide and ammonium)	1.5	140,000,000 (Nitrogen)	30% (Fossil fuel combustion)	2% (Traditional fuel burning)	67% (Fertilizer manufacturing, agricultural burning)	1% (Waste incineration)
Mercury emissions to the atmosphere	1.4	2500	20% (Fossil fuel combustion)	1% (Traditional fuel burning)	2% (Agricultural burning)	77% (Metals processing, manufacturing, waste incineration)
Nitrous oxide flows to the atmosphere	0.5	33,000,000	12% (Fossil fuel combustion)	8% (Traditional fuel burning)	80% (Fertilizer manufacturing, land clearing, aquifer disruption)	Negligible
Particulate emissions to the atmosphere	0.12	3,100,000,000	35% (Fossil fuel combustion)	10% (Traditional fuel burning)	40% (Agricultural burning)	15% (Smelting, urban land clearing, waste incineration)
Non-methane hydrocarbon emissions to the atmosphere	0.12	1,000,000,000	35% (Fossil fuel combustion)	5% (Traditional fuel burning)	40% (Agricultural burning)	20% (Urban land clearing, waste incineration)
Carbon dioxide emissions to the atmosphere	0.05		150,000,000,000	75% (Fossil fuel combustion)	3% (Net deforestation for fuelwood)	15% (Net deforestation from land clearing)
7% (Logging, cement manufacturing)						

Dimensions of Energy Security:

- Availability**
- Dependency
- Diversification
- Decentralization
- Innovation
- Investment
- Trade
- Production
- Price stability
- Affordability**

Dimensions of Energy Security:

- Governance
- Access**
- Reliability
- Literacy
- Resilience
- Land use
- Water
- Pollution
- Efficiency
- Greenhouse gas emissions

Governance

1. Transparency international corruption index
2. % Government revenue dependent on energy
3. Length of time it takes a new business to get electricity service
4. Frequency of review of country energy profile
5. Presence of climate change goals or targets
6. State fragility index rating
7. Worldwide Governance Indicators (World Bank)
8. Satisfaction (share of adult population satisfied with policy and planning mechanisms)
9. Number of annual protests relating to energy



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Evaluating energy security performance from 1990 to 2010 for eighteen countries

Benjamin K. Sovacool*, Ishani Mukherjee, Ira Martina Drupady, Anthony L. D'Agostino

Lee Kuan Yew School of Public Policy, National University of Singapore, 469C Bukit Timah Road, Singapore 259772

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ABSTRACT

This study provides an index for **evaluating national energy security policies and performance** among the **United States, European Union, Australia, New Zealand, China, India, Japan, South Korea**, and the **ten countries** comprising the **Association of Southeast Asian Nations (ASEAN)**. Drawn from research interviews, a survey instrument, and a focused workshop, the article first argues that energy security ought to be comprised of five dimensions related to **availability, affordability, technology development, sustainability, and regulation**. The article then breaks these dimensions down into **20 components** and correlates them with **20 metrics** that constitute a comprehensive energy security index. We find that the top three performers of our index for all data points and times are **Japan, Brunei**, and the **United States** and the worst performers **Vietnam, India**, and **Myanmar**. Malaysia, Australia, and Brunei saw their energy security improve the most from 1990 to 2010 whereas Laos, Cambodia, and Myanmar saw it decline the most. The article concludes by calling for more research on various aspects of our index and its results.

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energy experts. The lead author conducted 68 semi-structured research interviews over the course of February 2009 to November 2010 with senior energy security experts, including visits to the International Energy Agency, U.S. Department of Energy, United Nations Environment Program, Energy Information Administration, World Bank Group, Nuclear Energy Agency, and International Atomic Energy Agency. Participants at these institutions were asked:

- (1) Which dimensions of energy security are most important?
- (2) What metrics best capture these dimensions?
- (3) How might these metrics be used to create a common index or scorecard to measure national performance on energy security?

Table 1

Dimensions, components, and metrics comprising an energy security index.

Dimension	Component	Metric	Unit
Availability	Security of supply	Total primary energy supply per capita	Thousand tons of oil equivalent (ktoe)
	Production	Average reserve-to-production ratio for the three primary energy fuels (coal, natural gas, and oil)	Remaining years of production
	Dependency	Self-sufficiency	% Energy demand by domestic production.
	Diversification	Share of renewable energy in total primary energy supply	% of supply

Affordability	Stability	Stability of electricity prices	% Change
	Access	% Population with high quality connections to the electricity grid	% Electrification
	Equity	Households dependent on traditional fuels	% of population using solid fuels
	Affordability	Retail price of gasoline/petrol	Average price in US\$ for 100 L of regular gasoline/petrol PPP (adjusted for Purchasing Power Parity)

Technology development and efficiency	Innovation and research	Research intensity	% Government expenditures on research and development compared to all expenditures
	Energy efficiency Safety and reliability	Energy intensity Grid efficiency	Energy consumption per dollar of GDP % Electricity transmission and distribution losses
	Resilience	Energy resources and stockpiles	Years of energy reserves left

Environmental sustainability	Land use	Forest cover	Forest area as percent of land area
	Water	Water availability	% Population with access to improved water
	Climate Change	Per capita energy-related carbon dioxide emissions	Metric tons of CO ₂ per person
	Pollution	Per capita sulfur dioxide emissions	Metric tons of SO ₂ per person

Regulation and governance	Governance	Worldwide governance rating	Worldwide governance score
	Trade and connectivity	Energy exports	Annual value of energy exports in 2009 US\$ PPP (billions)
	Competition	Per capita energy subsidies	Cost of energy subsidies per person (2009 US\$ PPP)
	Information	Quality of energy information	% Data complete

Source: research interviews, energy security survey, and workshop discussion.

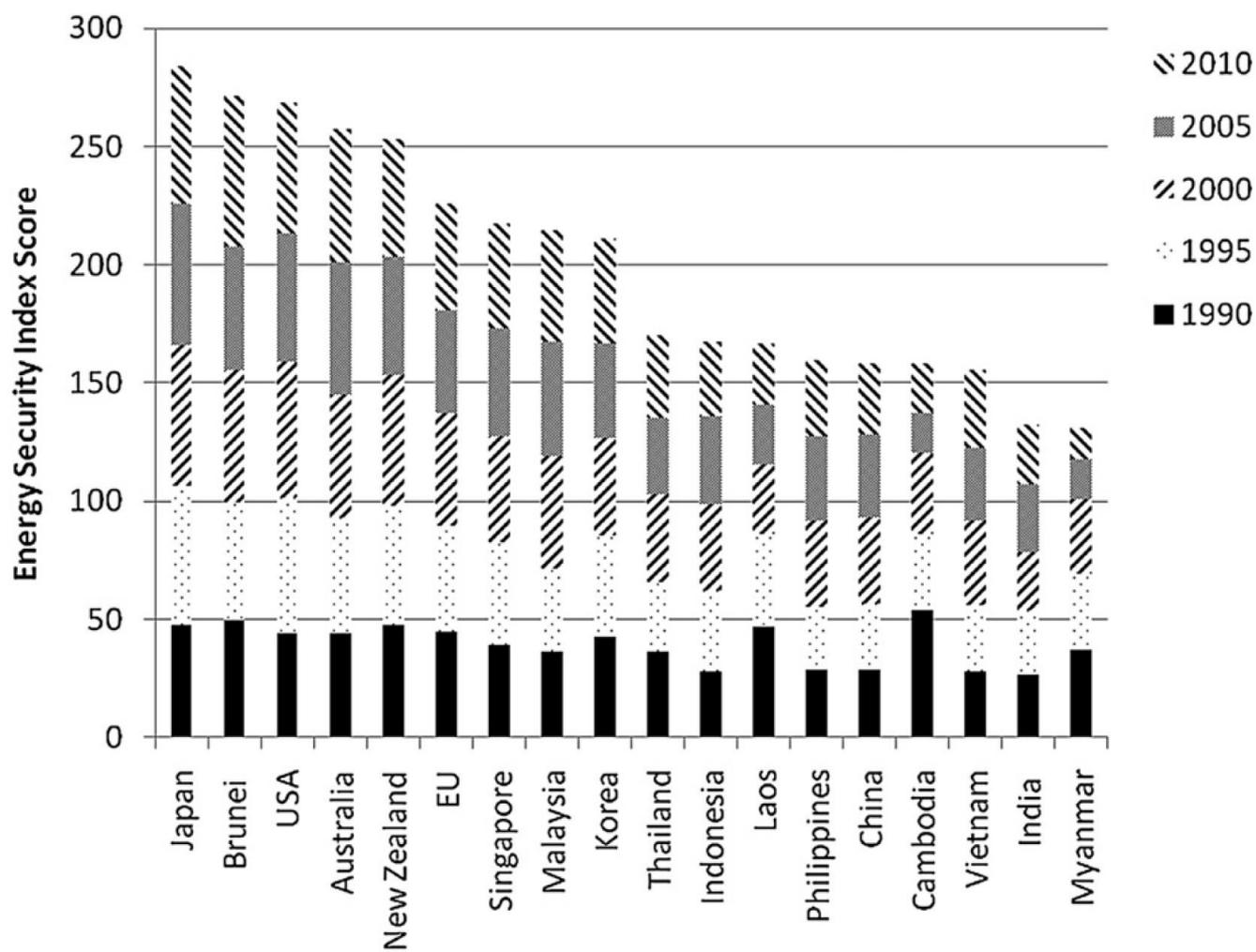


Fig. 2. Average energy security performance for eighteen countries.

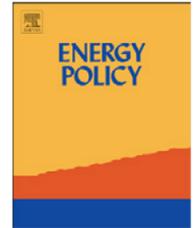
Though we are limited by space—and feel it appropriate that most of this paper focuses on research methods and data collection since that constituted the most time-consuming aspect of our project—we are able to offer a few preliminary results that should be very helpful at informing both energy policy and scholarship.

The first is that if one takes the mean score for each year and metric, and aggregates them, one gets a decent sense for who is most and worst energy secure among our sample of countries. The top three performers are Japan (284), Brunei, (271), and the United States (168) whereas the worst three performers are Vietnam (155), India (132), and Myanmar (131). [Fig. 2](#) presents these results disaggregated by year. Interestingly, the best possible score a country could have gotten—if it excelled in every category, for every year—was 500, indicating clearly that even the “best” performers still had aspects of their energy security that were unfavorable.



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Forum

From a hard place to a rock: Questioning the energy security of a coal-based economy

Benjamin K. Sovacool^{a,*}, Christopher Cooper^b, Patrick Parenteau^c

^a Centre on Asia and Globalisation, Lee Kuan Yew School of Public Policy, National University of Singapore, Oei Tiong Ham Building, 469C Bukit Timah Road, Singapore 259772, Singapore

^b Institute for Energy and Environment, Vermont Law School, Royalton, VT, USA

^c Environmental and Natural Resources Law Clinic, Vermont Law School, Royalton, VT, USA

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ABSTRACT

We thank Brathwaite et al. for starting a very useful debate about **what role, if any, coal should play in future energy transitions**. Expanding upon their piece, we **question** that a **coal-based economy**, in which energy production for both electricity and transport comes from coal, **can meet the energy security needs of the United States and other countries**.

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1. Introduction

“Frosty the Coalman, he’s getting cleaner every day.
He’s affordable and adorable and the workers keep their pay.
He’s abundant here in America,
And he helps our economy roll...”
The Clean Coal Carolers

Table 1

Four criteria of energy security.

Criteria	Underlying values	Explanation
Availability	Independence and diversification	Diversifying the fuels used to provide energy services as well as the location of facilities using those fuels, promoting energy systems that can recover quickly from attack or disruption, operating a reliable system, and minimizing dependence on foreign suppliers
Affordability	Equity	Providing energy services that are affordable for consumers and minimizing price volatility
Efficiency	Innovation and consumer education	Improving the performance of energy equipment and altering consumer behavior
Stewardship	Social and environmental sustainability	Protecting the natural environment, communities and future generations

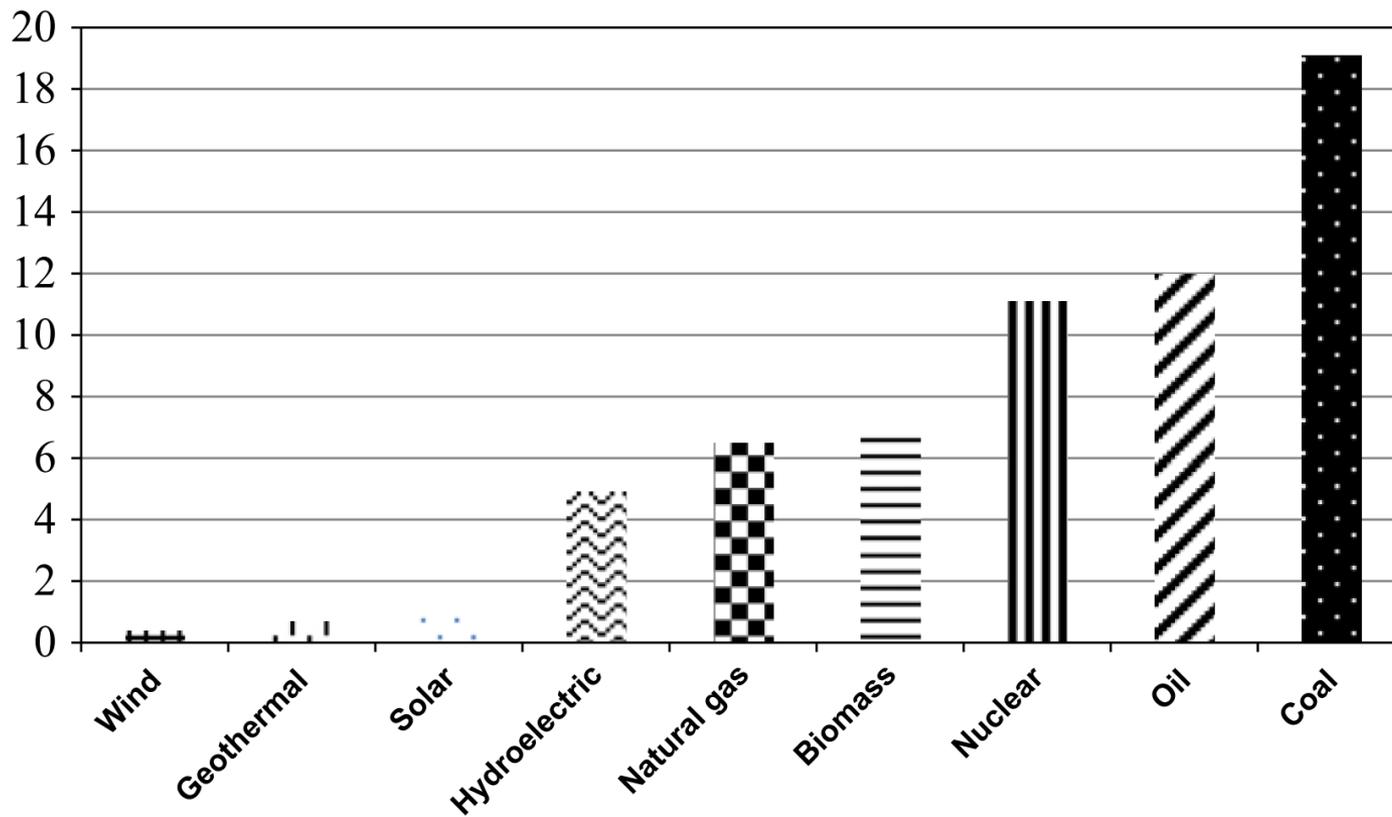


Fig. 1. Environmental externalities associated with electricity generation technologies (2007 U.S. Cents/kW h).

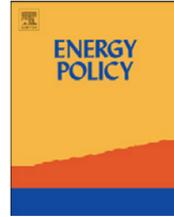
Source: Sovacool (2008).



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India's energy security: A sample of business, government, civil society, and university perspectives

Malavika Jain Bambawale*, Benjamin K. Sovacool

Energy Governance Program, Centre on Asia and Globalisation, Lee Kuan Yew School of Public Policy, National University of Singapore, Oei Tiong Ham Building, 469C Bukit Timah Road, Singapore 259772, Singapore

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ABSTRACT

This article explores the **concept of energy security** perceived and understood by a sample of **government, business, civil society, and university stakeholders in India**. Based on a literature review, the authors hypothesize what energy experts suggest energy security is for India. The article then tests these hypotheses through the use of a **survey completed by 172 Indian respondents**. The article begins by describing its methodology before summarizing the results of the literature review to distill **seven working hypotheses** related to energy security in India. These hypotheses relate to (1) security of energy supply, (2) equitable access to energy services, (3) research and development of new energy technologies, (4) energy efficiency and conservation, (5) self-sufficiency and trade in energy fuels, (6) nuclear power, and (7) the energy-water nexus. It then tests these hypotheses with our survey instrument before concluding with implications for energy policy in India and beyond.

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Table 1

Key features of the Indian energy sector 2010.

Source: International Energy Agency 2010; World Bank 2010; U.S. Energy Information Administration 2010.

Annual net imports of crude oil	128 million metric tons
Annual net imports of coal	66 million metric tons
Annual electricity generated from fossil fuels	34 TWh
Total primary energy supply	620.97 million tons of oil equivalent
Total import dependence ratio	24.6%
Total electricity consumption	645.25 TWh
Annual carbon dioxide emissions from fuel combustion	427.64 million tons
Energy intensity	0.14 tons of oil per US\$100 of Gross Domestic Product (GDP)
Total electrification rate	64.5%
Urban electrification rate	93.1%
Rural electrification rate	52.5%
Population without electricity	404.5%

H1: Security of supply

One would expect a developing economy in countries such as India, which lacks sufficient domestic resources, but has rapidly growing demand for energy, to give paramount importance to security of supply of fossil fuels.

H2: Equitable access

With electricity access limited to only 65% of the population, one would expect a high level of importance to be placed on resolving energy poverty and issues of equitable access, especially among policymakers and those working in the non-profit sector.

H3: R&D

With power capacity shortages of 15% of peak demand, and only 8% installed capacity in renewable energy, one would expect India's policymakers to place a high level of importance to R&D and to developing renewable sources of energy.

H4: Energy efficiency

Given that there is scope for energy efficiency improvements especially in the commercial and residential sectors, one would expect the Indian private sector to place a premium on low energy intensity.

H5: Self-sufficiency and trade

Given that self-sufficiency has been an important dimension of India's political strategy, and that there have been high levels of activity in acquiring foreign strategic assets as opposed to trading in the open market, one would expect a low rating given to trade in energy products

H6: Nuclear energy

Given the importance of nuclear energy to Indian energy policy, one would expect respondents of the survey to place a high importance on centralized (as opposed to decentralized) systems, R&D in new energy technologies, and availability of uranium and thorium.

H7: The energy-
water nexus

One would expect Indians to put a premium on availability of water when talking of energy security, given the strong linkage between energy and water, and the severe shortage of water faced in many parts of India.

Table 2

Percentage of respondents ranking the dimension as first or second in importance.

How many respondents ranked this dimension first or second in importance

to have a secure supply of coal, gas, oil, and/or uranium	40%
to promote trade in energy products, technologies, and exports	4%
to minimize depletion of domestically available energy fuels	13%
to have stable, predictable, and clear price signals	8%
to have affordably priced energy services	20%
to have small-scale and decentralized energy systems	8%
to have low energy intensity (unit of energy required per unit of economic output)	10%
to conduct research and development on new and innovative energy technologies	25%
to assure equitable access to energy services to all of its citizens	8%
to ensure transparency and participation in energy permitting, siting, and decision-making	5%
to inform consumers and promote social and community education about energy issues	21%
to minimize the destruction of forests and the degradation of land and soil	9%
to provide available and clean water	20%
to minimize air pollution	15%
to minimize the impact of climate change (i.e., adaptation)	8%
to reduce greenhouse gas emissions (i.e., mitigation)	8%

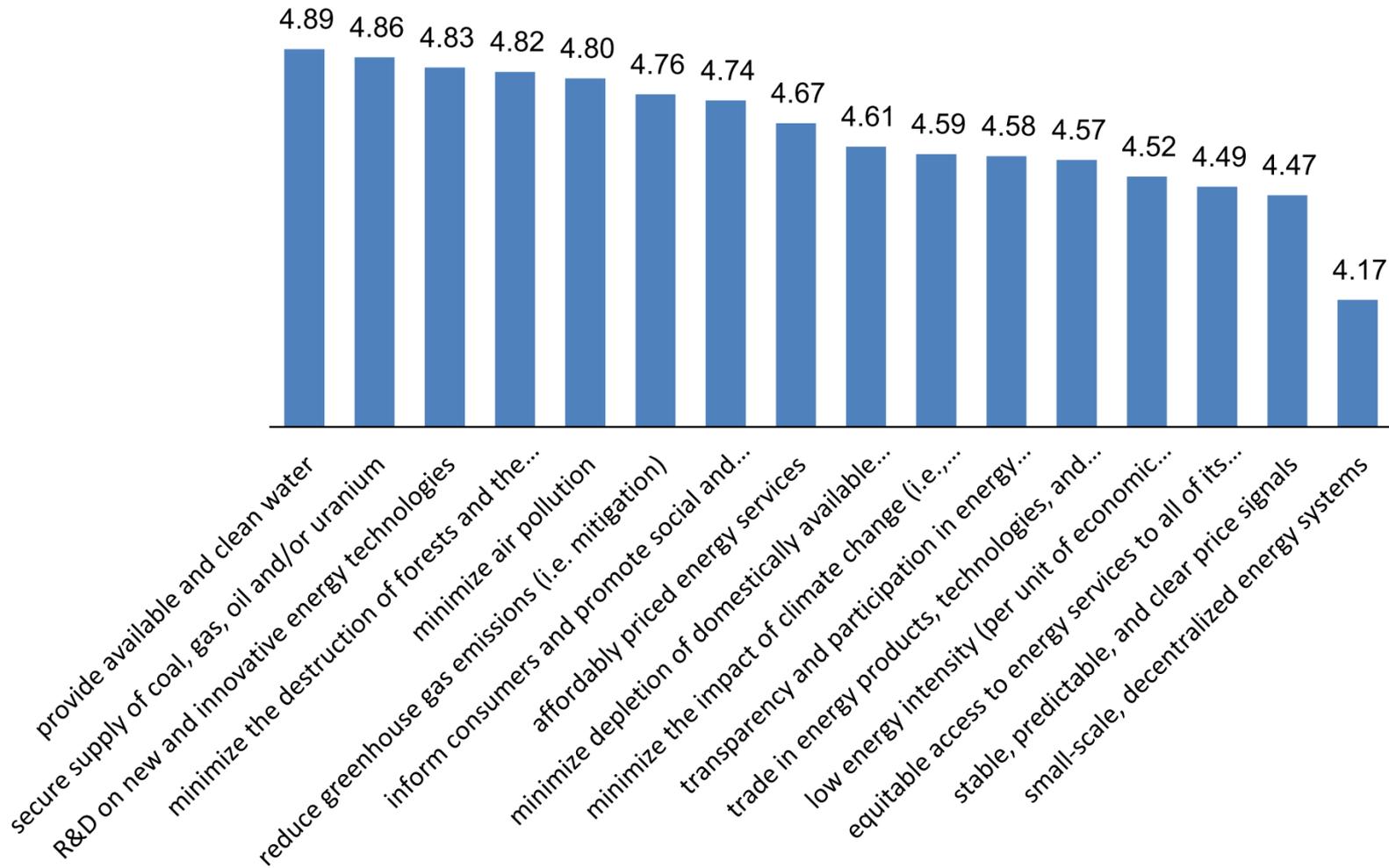


Fig. 2. Average rating given to the dimension based on an importance scale from 1 to 5 (5=extremely important, 1=extremely unimportant).

Table 3

Ratings to energy security dimensions by different occupation categories.

Dimension	Private sector	University	Non profit	Government	Inter-governmental
to have a secure supply of coal, gas, oil and/or uranium	5.0	4.9	4.6	4.9	4.8
to promote trade in energy products, technologies, and exports	4.8	4.6	4.5	4.4	4.6
to minimize depletion of domestically available energy fuels	4.5	4.6	4.8	4.7	4.5
to have stable, predictable, and clear price signals	4.6	4.3	4.5	4.7	4.5
to have affordably priced energy services	4.7	4.7	4.6	4.8	4.5
to have small-scale, decentralized energy systems	3.8	4.2	4.3	4.2	4.1
to have low energy intensity (unit of energy required per unit of economic output)	4.4	4.5	4.6	4.6	4.5
to conduct research and development on new and innovative energy technologies	4.9	4.8	4.8	4.8	4.6
to assure equitable access to energy services to all of its citizens	4.3	4.5	4.6	4.7	4.2
to ensure transparency and participation in energy permitting, siting, and decision-making	4.7	4.6	4.5	4.7	4.5
to inform consumers and promote social and community education about energy issues	4.5	4.8	4.8	4.8	4.6
to minimize the destruction of forests and the degradation of land and soil	4.9	4.8	5.0	4.8	4.5
to provide available and clean water	4.8	4.9	5.0	5.0	4.7
to minimize air pollution	4.9	4.8	4.8	4.9	4.7
to minimize the impact of climate change (i.e., adaptation)	4.7	4.6	4.4	4.7	4.5
to reduce greenhouse gas emissions (i.e. mitigation)	4.7	4.8	4.8	4.9	4.1

Note: Green stands for relatively high ratings, yellow for medium and red for low ratings.

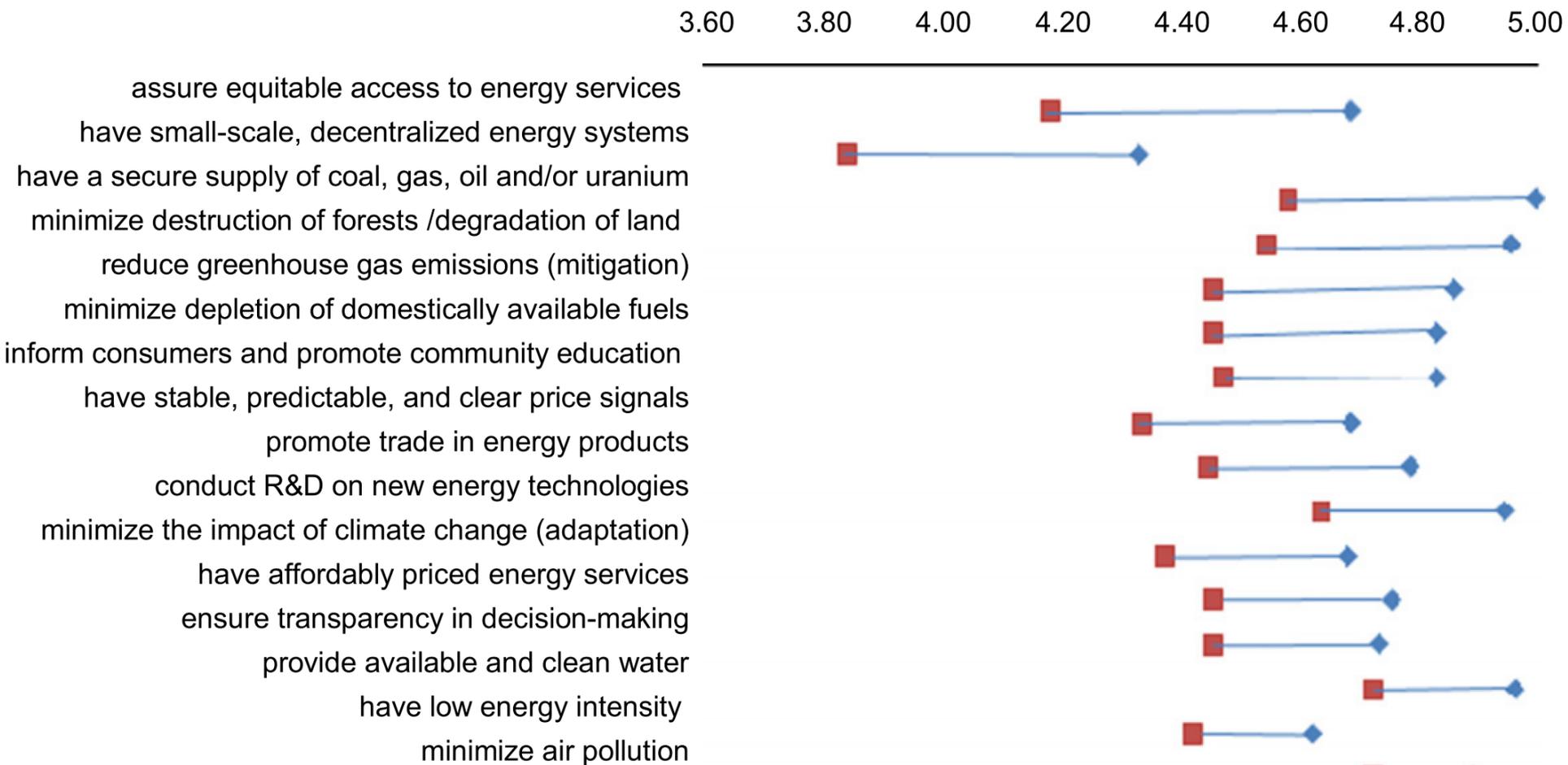


Fig. 3. The range of ratings across different occupational groups in decreasing order of magnitude, for all 16 dimensions.

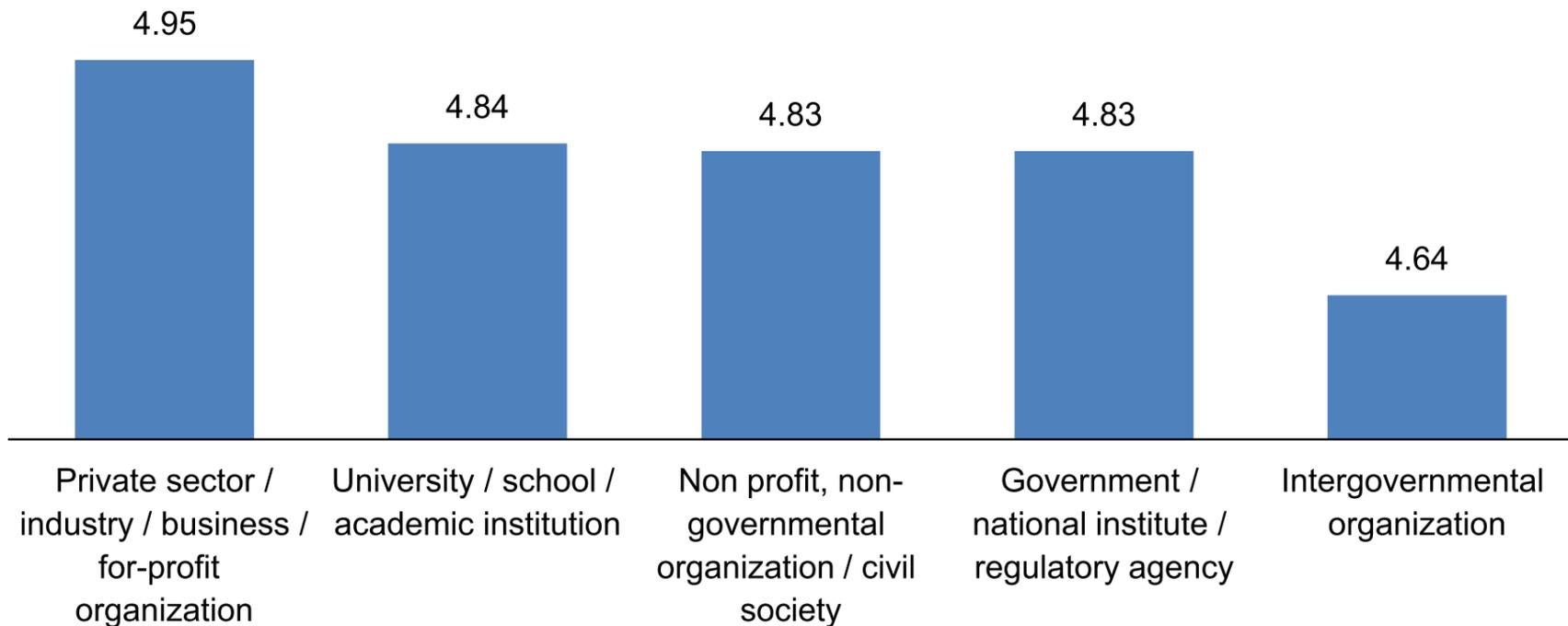


Fig. 4. Ratings for “to conduct R&D on new and innovative energy technologies” by respondents in different occupation categories.

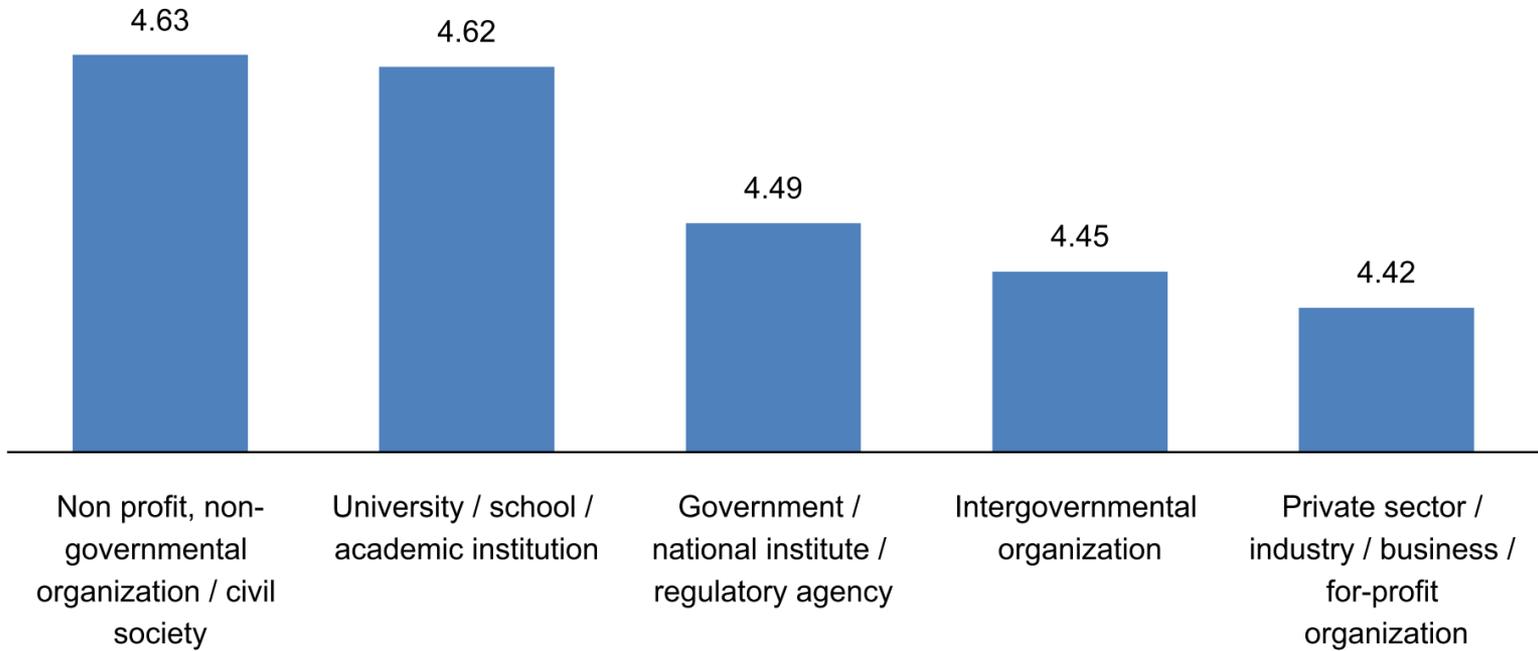


Fig. 5. Ratings for “low energy intensity (unit of energy required per unit of economic output)” by respondents in different occupation categories.

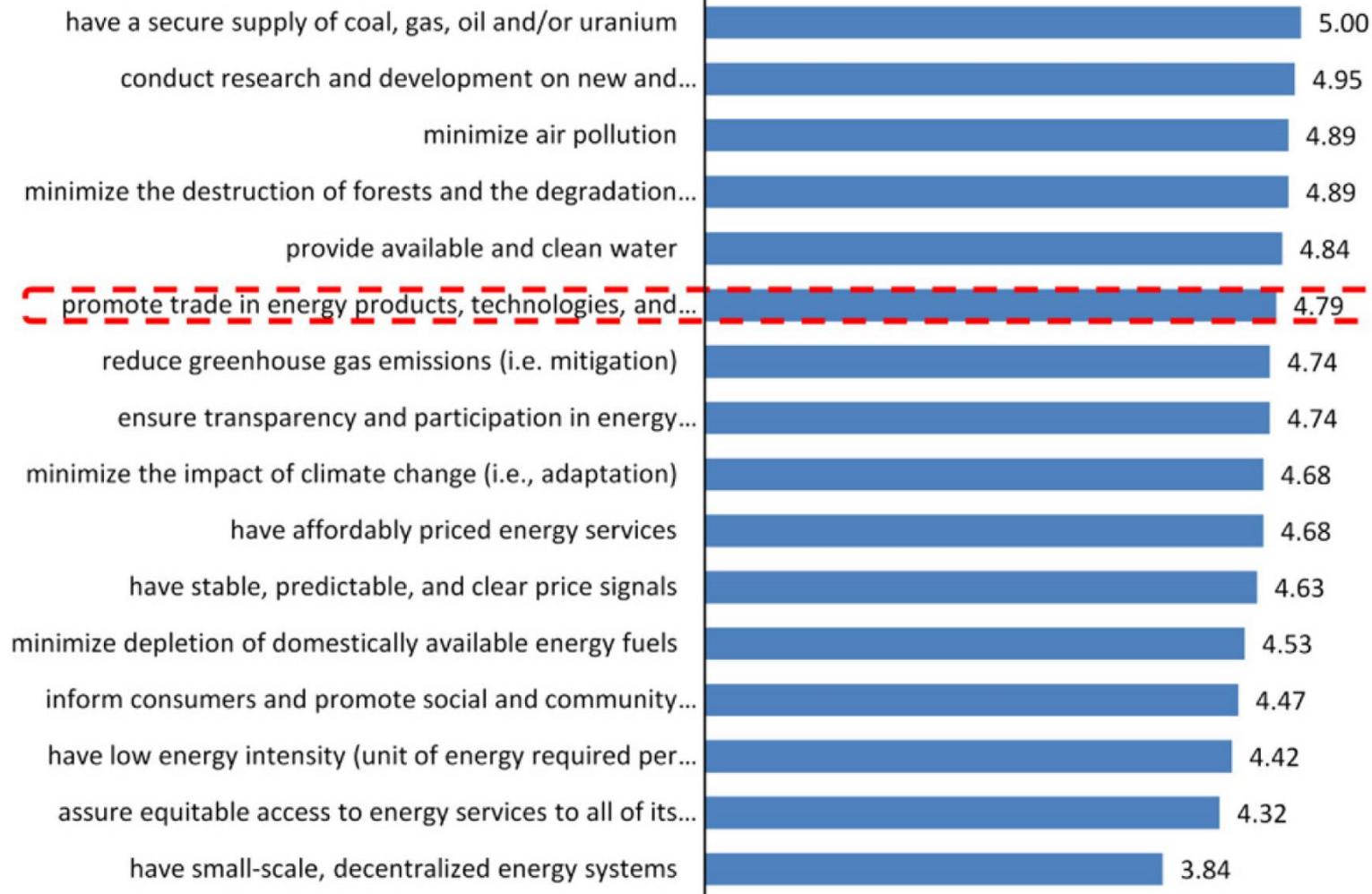


Fig. 6. The private sector's ratings of 16 dimensions.

Annex A. The survey

Energy security survey

You are invited to participate in a research project on energy security. The aim of the project is to explore the different dimensions of energy security. The survey will take between 10 and 15 min to complete, and all aspects of the study, including results, will be strictly confidential and only the researchers will have access to information on participants. A book and/or series of academic articles about the study may be submitted for publication, but individual participants will not be identifiable in any of the published findings. No monetary reimbursement or compensation will be given for participation. However, if the participant is interested in the final results and/or resultant publications of the research study, then the information will be provided. Your decision to participate in this research is voluntary and completely up to you. All interview and survey questions are optional. If you do not feel comfortable at, anytime, you may terminate the survey for any reason. Please think about the key energy-related challenges facing your country of residence when filling out this survey.

SECTION 1

1. Please tell us about yourself:

a. Level of education: Postgraduate Undergraduate Secondary Other

b. Age: 18 to 25 26 to 35 36 to 45 46 to 55 55 and above

c. Gender: Male Female

d. Country of residence:

United States

Brazil

Russia

China

India

Kazakhstan

Papua New Guinea

Saudi Arabia

Singapore

Japan

Germany

e. Nationality: _____

f. Type of occupation:

Private sector/industry/business/for-profit organization

Non-profit, non-governmental organization/civil society

Government/national institute/regulatory agency

University/school/academic institution

Intergovernmental organization

g. Name of primary employer (optional):

h. Job title (optional) _____

SECTION 2

2. When you think about energy security for your country of residence in the next 5 years, how important is it

	Extremely important	Somewhat important	Neither important nor unimportant	Somewhat unimportant	Extremely unimportant
...to have a secure supply of oil, gas, coal, and/or uranium	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to promote trade in energy products, technologies, and exports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to minimize depletion of domestically available energy fuels	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to have stable, predictable, and clear price signals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to have affordably priced energy services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to have small-scale and decentralized energy systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to have low energy intensity (unit of energy required per unit of economic output)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to conduct research and development on new and innovative energy technologies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to assure equitable access to energy services to all of its citizens	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to ensure transparency and participation in energy permitting, siting, and decision-making	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to inform consumers, and promote social and community education about energy issues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to minimize the destruction of forests and the degradation of land and soil	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to provide available and clean water	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to minimize air pollution	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to minimize the impact of climate change (i.e., adaptation)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...to reduce greenhouse gas emissions (i.e. mitigation)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

SECTION 3

3. Given the 16 dimensions of energy security discussed here, select the five that you think are most important for your country of residence, and rank them from 1 (the most important) to 5 (5th most important), without allowing for ties. Please rank only 5 dimensions:

- | | |
|---|---|
| <input type="checkbox"/> Secure supply of oil, gas, coal, and uranium | <input type="checkbox"/> Transparency and participation in siting and decision-making |
| <input type="checkbox"/> Bolstering trade | <input type="checkbox"/> Education and information |
| <input type="checkbox"/> Minimizing rates of depletion | <input type="checkbox"/> Preservation of land |
| <input type="checkbox"/> Predictable and clear price signals | <input type="checkbox"/> Availability and quality of water |
| <input type="checkbox"/> Affordably priced energy services | <input type="checkbox"/> Minimal air pollution |
| <input type="checkbox"/> Decentralization and small-scale supply | <input type="checkbox"/> Responding to climate change/adaptation |
| <input type="checkbox"/> Low energy intensity | <input type="checkbox"/> Reducing greenhouse gas emissions/mitigation |
| <input type="checkbox"/> Research and development | |
| <input type="checkbox"/> Equitable access | |

4. Did we miss any dimension that you consider important for the energy security of your country of residence in the next five years? Please enter below (or if we did not, then leave blank)

If you did provide an answer, when you think about energy security for your country of residence in the next five years, how important is this above dimension?

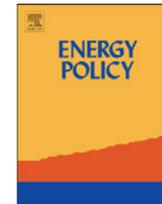
- Extremely important
 Somewhat important
 Neither important nor unimportant
 Somewhat unimportant
 Extremely unimportant



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Behind an ambitious megaproject in Asia: The history and implications of the Bakun hydroelectric dam in Borneo

Benjamin K. Sovacool*, L.C. Bulan

Lee Kuan Yew School of Public Policy, National University of Singapore, Oei Tiong Ham Building, 469C Bukit Timah Road, Singapore 259772, Singapore

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ABSTRACT

Using a **case-study, inductive, narrative approach**, this article explores the **history, drivers, benefits, and barriers** to the **Bakun Hydroelectric Project in East Malaysia**. Situated on the island of Borneo, Bakun Dam is a 204 m high concrete face, rock filled dam on the Balui River in the Upper Rajang Basin in the rainforests of Sarawak. Bakun Dam and its affiliated infrastructure could be the single largest and most expensive energy project ever undertaken in Southeast Asia. Based on data collected through site visits, original field research in Sarawak, and **more than 80 research interviews**, the article begins by teasing out the complex history and drivers behind the Bakun project before identifying a set of potential **social, political, and economic benefits** the project could deliver. It then delves into **six sets of barriers** in the technical, economic, political, legal and regulatory, social, and environmental realms. We find that Bakun illustrates how **centralized energy megaprojects**, while ostensibly championed for reasons of **economies of scale** and the ability to bring about transformational change in the shortest period of time, often **fail to address broader development goals** such as fighting **energy poverty** and improving the **livelihoods** of the **local communities** they are supposed to serve.

A B S T R A C T

Using a case-study, inductive, narrative approach, this article explores the history, drivers, benefits, and barriers to the Bakun Hydroelectric Project in East Malaysia. Situated on the island of Borneo, Bakun Dam is a 204 m high concrete face, rock filled dam on the Balui River in the Upper Rajang Basin in the rainforests of Sarawak. Bakun Dam and its affiliated infrastructure could be the single largest and most expensive energy project ever undertaken in Southeast Asia. Based on data collected through site visits, original field research in Sarawak, and more than 80 research interviews, the article begins by teasing out the complex history and drivers behind the Bakun project before identifying a set of potential social, political, and economic benefits the project could deliver. It then delves into six sets of barriers in the technical, economic, political, legal and regulatory, social, and environmental realms. We find that Bakun illustrates how centralized energy megaprojects, while ostensibly championed for reasons of economies of scale and the ability to bring about transformational change in the shortest period of time, often fail to address broader development goals such as fighting energy poverty and improving the livelihoods of the local communities they are supposed to serve.

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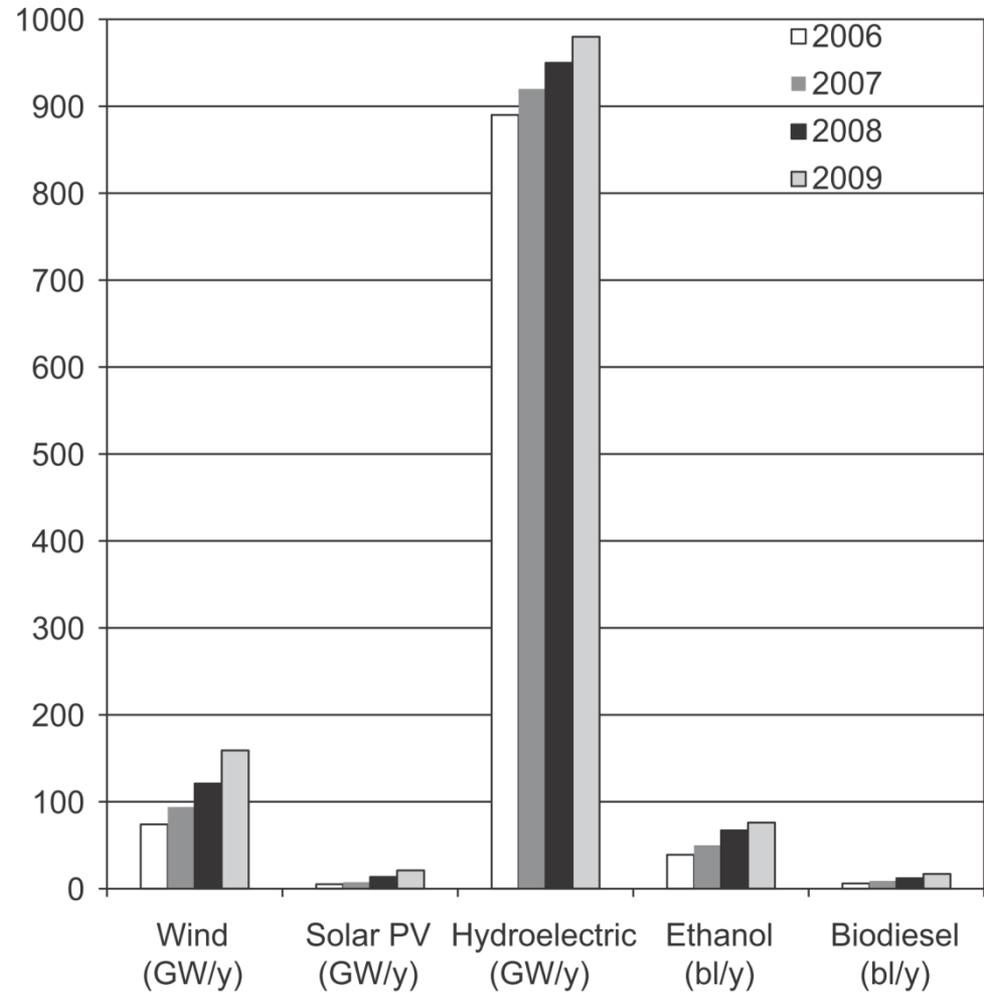


Fig. 1. New global installed capacity for select renewable energy systems, 2006–2009.

Table 2
Barriers to large-scale energy projects in Southeast Asia.

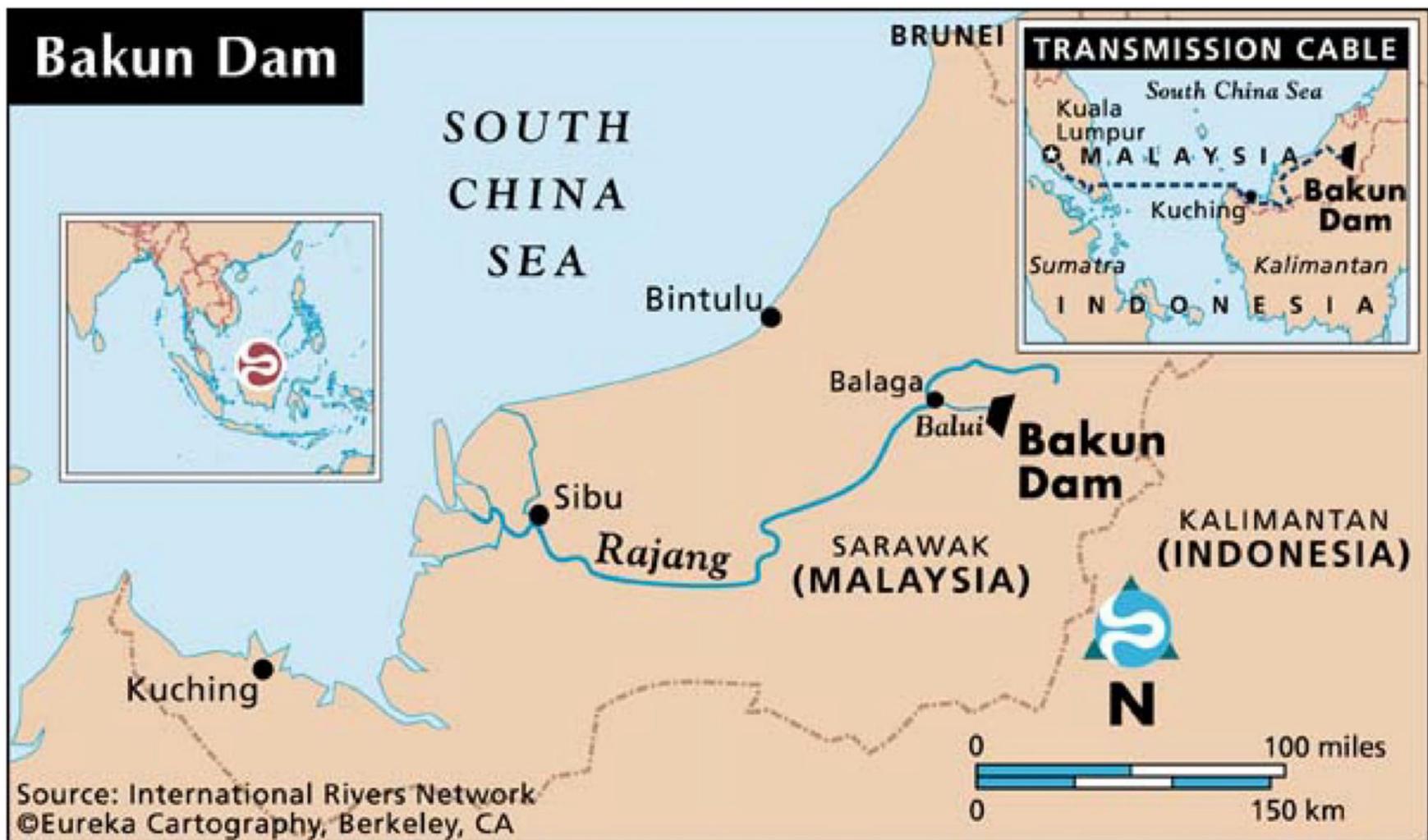
Technical	Economic	Legal	Political	Social	Environmental
Infrastructure construction and operation	Uncertainty surrounding energy reserves	Inconsistent regulatory frameworks	Contests over sovereignty	Poor participatory mechanisms	Land degradation
	Unknown future energy demand	Unclear protection of property rights	Diplomatic tensions	Lack of transparency	Accidents and spills
	Capital intensity	State control of markets	Protectionism	Relocation, resettlement, and human rights concerns	Greenhouse gas emissions and climate change
	Financing	Weak mechanisms for dispute settlement	Lack of sustained leadership		
	Returns on investment	Disagreements over prices and tariffs			



Fig. 2. Front side of the Bakun Hydroelectric Project, July 2010.



Bakun Dam



Source: International Rivers Network
©Eureka Cartography, Berkeley, CA

Fig. 3. Location of the Bakun Dam in Sarawak, Malaysia.

happen.” As another participant commented:

The key energy security challenge for all of Malaysia, defined in terms of supply and demand, is how to get the resources in states like Sarawak or Sabah to urban centers. We have an obvious mismatch between energy resources and energy demand. Everything important, politically and economically, happens in Peninsular Malaysia, but the resources are in Sabah and Sarawak, which creates a very complicated picture. Bakun is a tool for getting those resources where they need to go.

Table 5

Summary of the socio-technical barriers facing the Bakun Hydroelectric Project.

Category	Explanation
Technical	Sedimentation and rainfall/hydrology Geographic isolation of Sarawak/lack of supporting infrastructure Excavation and construction Skilled manpower/coordination of contractors/logistical challenges
Economic	Capital cost/cost overrun Financing/lack of interest with investors Power purchase agreement Little economic diversification/improvement to community welfare
Political	Cancellation of undersea cable Inadequate planning Corruption and nepotism Low political literacy and representation

Legal and regulatory

Restrictive land code/changing of land code
Lack of a national energy policy
Lawsuits and NGOs/flawed EIAs
Commitment to fossil fuels/subsidies

Social

Community relocation and resettlement
Boom and bust towns/inflation
Navigation/community livelihood
Unfair compensation

Environmental

Land clearing/deforestation
Greenhouse emissions
Changes to hydrology, water quality, and river flow
Downstream impacts from aluminum smelting



Fig. 6. An aerial view of sedimentation entering the coast of Sarawak in the Mukah Basin.

Other respondents blamed *inadequate planning* on the part of government leaders. As one commented:

The ability of the Malaysian government to execute these projects is incredibly poor. The idea of long-termism is not heavily instilled in the Malaysian psyche, most politicians and leaders are looking only at how to get rich or maintain their power for the next 5 years, or getting in and out. We are not used to thinking about the long-term, and this becomes a meaningful impediment when trying to manage infrastructure projects that can span decades.

change.” Yet another commented that:

It is hard to change the political structure here in Sarawak. Only five people of the entire Penan ethnic community actually voted in the last election, and only a small handful have IC cards and are registered to vote. The government refuses to give the rest of us identity cards, like we are invisible to them. We cannot even vote or take effective political action.

A second regulatory barrier concerns the *lack of a national energy policy*. As one respondent lamented:

Malaysia does not even have a national energy policy, really we only have a mishmash of different policies for oil, natural gas or coal, but nothing really for renewable energy, and energy efficiency, lacunae due to fragmentation and lack of political will.

Table 6

Native communities displaced by the Bakun Hydroelectric Project.

Source: Research interviews; [Onn \(2010\)](#).

Ethnic group	Longhouses	Families	Population
Kenyah	4	1024	4708
Kayan	8	881	3781
Lahanan	1	138	535
Ukit	1	74	104
Penan	1	24	104
Total	15	2141	9428

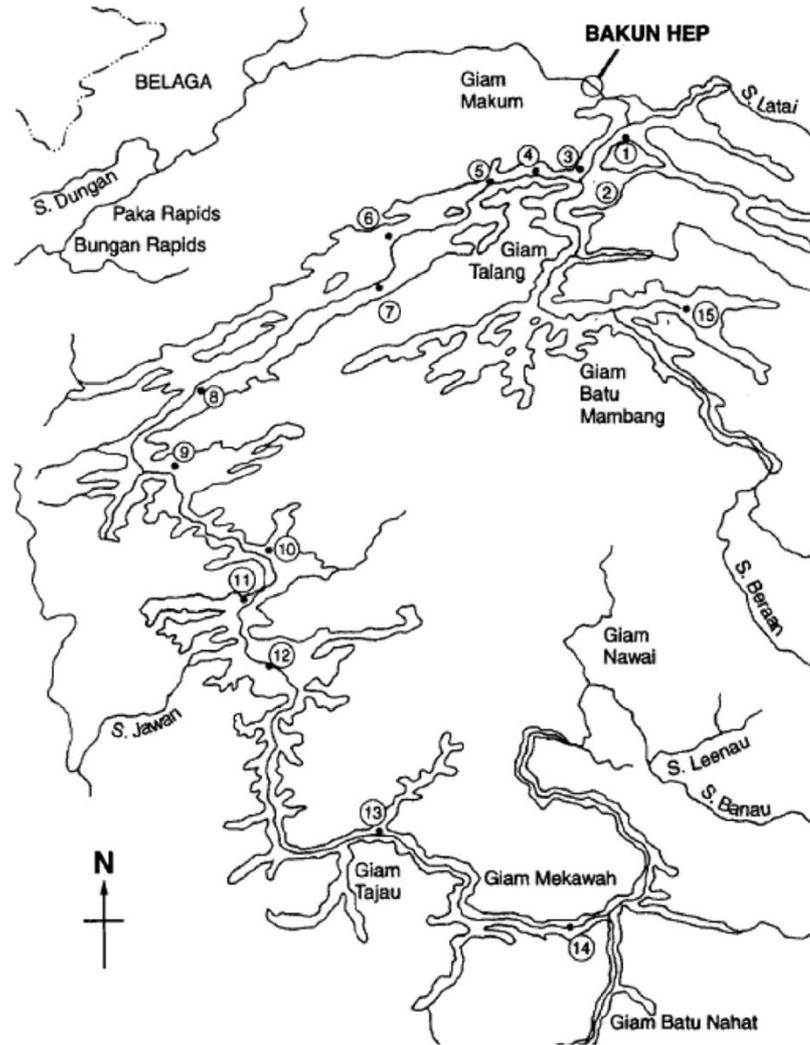


Fig. 7. Geographic location of native communities displaced by the Bakun Hydroelectric Project.

Table 7

Expected environmental impacts from the Bakun Hydroelectric Project.

Source: Ekran Berhad (1995a, 1995b, 1995c, 1995d, 1995e).

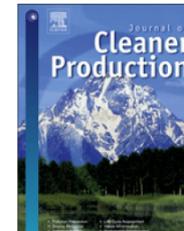
Stage	Environmental impact
Clearing and construction	Increased turbidity
	Loss of pool nursery habitat
	Reduced organic input Impaired migration
Impoundment	Reduced river flow, turbidity, and organic input
	Loss of habitat due to reduced water depth
	Reduced reservoir turbidity
	Increased phytoplankton production
	Impaired fish migration Replacement of natural riverine habitat with artificial deep lake habitat
Operation	Reduced river turbidity
	Reduced river dissolved oxygen content
	Increased hydrogen sulfide
	Impaired fish migration
	Altered upstream species composition
	Replacement of native riverine species with lake-adapted species in reservoir



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Seven suppositions about energy security in the United States

Benjamin K. Sovacool*

Lee Kuan Yew School of Public Policy, National University of Singapore, 469C Bukit Timah Road, Singapore 259772, Singapore

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ABSTRACT

Changing the patterns of energy use requires investigating how **energy consumers – not experts – conceive of energy challenges**. This article explores the varying **beliefs, attitudes, and views on energy security** in the United States among **experts and residents**. Based primarily on an **academic literature review** to distill **expert views**, and a **survey** distributed to **hundreds of residents in the U.S.** to capture **consumer views**, the study begins by explaining its methodology before identifying seven suppositions related to energy security. These suppositions involve security of fuel supply, energy democracy, energy research and development, affordability of energy services, environmental pollution, and climate change adaptation and mitigation. The second section of the study tests these suppositions with a **survey** distributed to **427 respondents** in the United States. Three suppositions are supported, two are unsupported, and two are neither supported nor unsupported. The final section of the study offers implications for U.S. energy policy and scholarship.

A B S T R A C T

Changing the patterns of energy use requires investigating how energy consumers – not experts – conceive of energy challenges. This article explores the varying beliefs, attitudes, and views on energy security in the United States among experts and residents. Based primarily on an academic literature review to distill expert views, and a survey distributed to hundreds of residents in the U.S. to capture consumer views, the study begins by explaining its methodology before identifying seven suppositions related to energy security. These suppositions involve security of fuel supply, energy democracy, energy research and development, affordability of energy services, environmental pollution, and climate change adaptation and mitigation. The second section of the study tests these suppositions with a survey distributed to 427 respondents in the United States. Three suppositions are supported, two are unsupported, and two are neither supported nor unsupported. The final section of the study offers implications for U.S. energy policy and scholarship.

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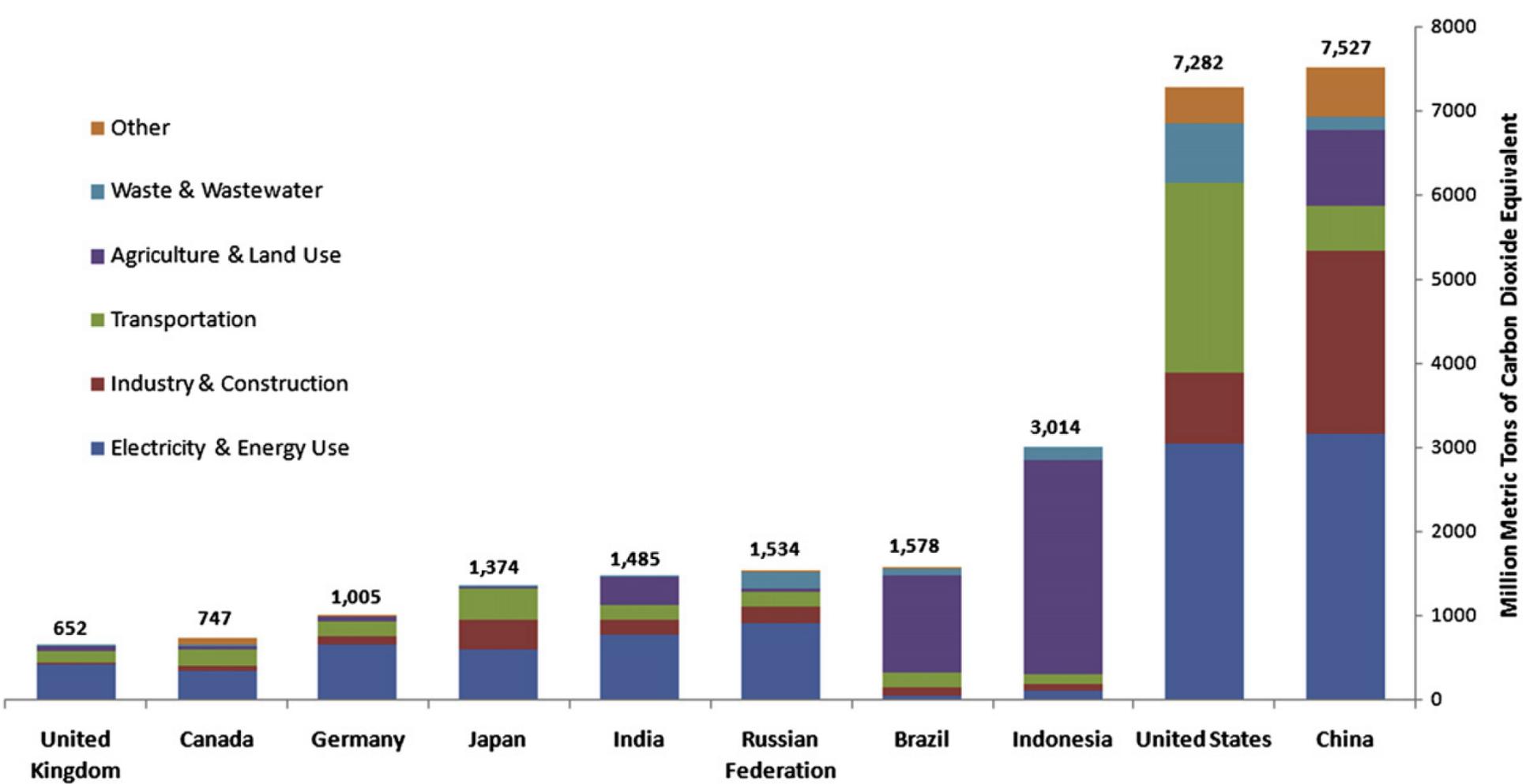


Fig. 1. Overview of the share of greenhouse gas emissions for the top ten countries, 2008. Source: Brown and Sovacool (2011). 140

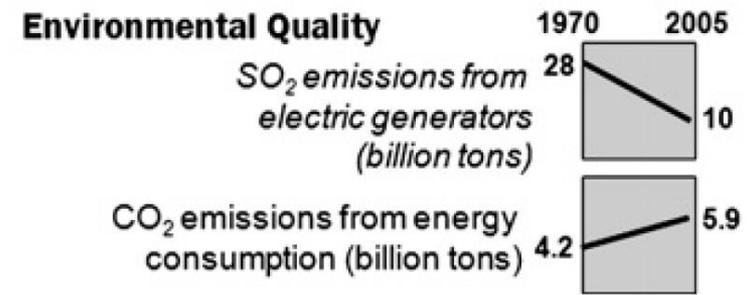
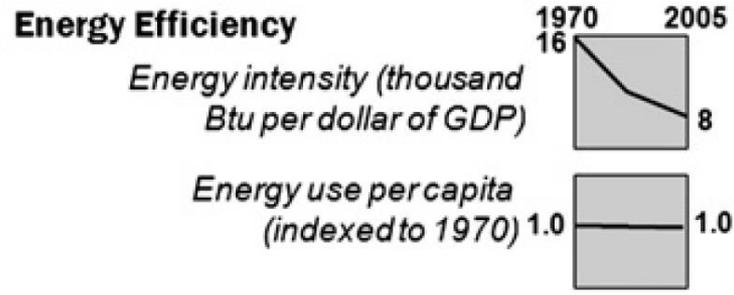
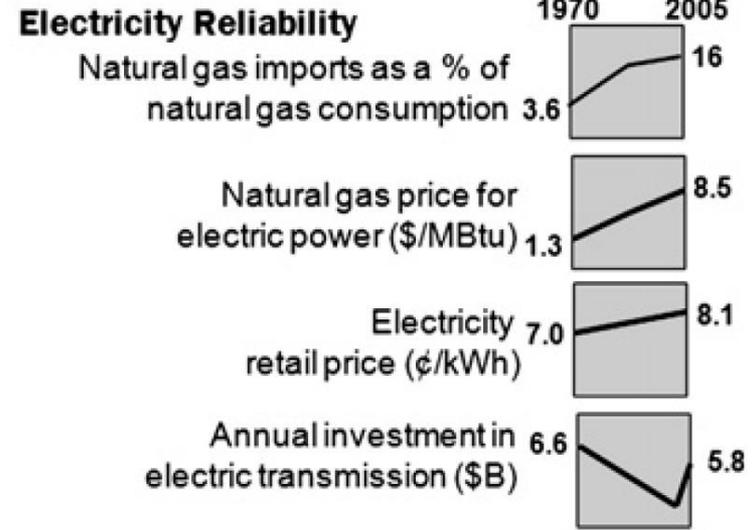
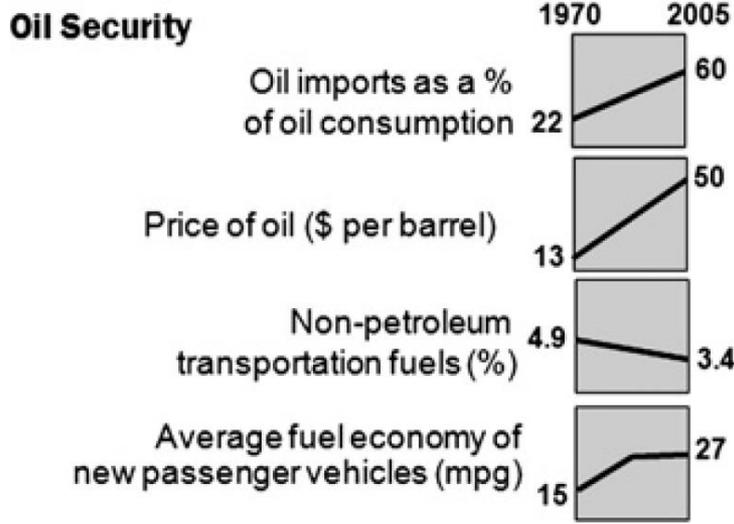


Fig. 2. National U.S. Energy Sector Performance, 1970–2005. Source: [Brown and Sovacool \(2007\)](#). Items in italics represent the only three metrics where performance improved.

Table 1

Seven expert suppositions about U.S. energy security.

Supposition	Explanation	Survey question(s)
S1: Security of supply and trade	One would expect a country such as the U.S., dependent on imports, to give paramount importance to security of fossil fuel supply	(a) When you think about energy security for your country of residence in the next five years, how important is it to have a secure supply of oil, gas, coal, and/or uranium? (b) When you think about energy security for your country of residence in the next five years, how important is it to promote trade in energy products, technologies, and exports?
S2: Energy democracy	Given the U.S. commitment to democracy, and recent protests over the siting of energy facilities, one would expect high ratings given to openness, public participation, and decentralization	(a) When you think about energy security for your country of residence in the next five years, how important is it to have small-scale, decentralized energy systems? (b) When you think about energy security for your country of residence in the next five years, how important is it to ensure transparency and participation in energy permitting, siting, and decision-making? (c) When you think about energy security for your country of residence in the next five years, how important is it to inform consumers and promote social and community education about energy issues?
S3: Energy research	Given the amount it spends on public and private research, one would expect the U.S. to highly rate research and development of new energy systems	(a) When you think about energy security for your country of residence in the next five years, how important is it to conduct research and development on new and innovative energy technologies?

S4: Energy efficiency	Given the massive efforts in energy efficiency going back to the Carter Administration, one would expect the efficient use of energy resources to be rated as an important energy security concern	(a) When you think about energy security for your country of residence in the next five years, how important is it to have low energy intensity (unit of energy required per unit of economic output)?
S5: Affordability	Given recent efforts at electricity restructuring, and rising oil prices, one would expect an emphasis on lower, more equitable, and stable energy prices	(a) When you think about energy security for your country of residence in the next five years, how important is it to have affordably priced energy services? (b) When you think about energy security for your country of residence in the next five years, how important is it to have stable and predictable price signals? (c) When you think about energy security for your country of residence in the next five years, how important is it to equitably provide access to energy services?
S6: Environmental pollution	Given the strength of the environmental movement there, one would expect a high priority given to issues involving energy-based environmental degradation	(a) When you think about energy security for your country of residence in the next five years, how important is it to minimize the destruction of forests and the degradation of land and soil? (b) When you think about energy security for your country of residence in the next five years, how important is it to provide? Available and clean water? (c) When you think about energy security for your country of residence in the next five years, how important is it to minimize air pollution?
S7: Climate change	Given recent public surveys, one would expect a high rating given to climate change	(a) When you think about energy security for your country of residence in the next five years, how important is it to minimize the impact of climate change (i.e., adaptation)? (b) When you think about energy security for your country of residence in the next five years, how important is it to reduce greenhouse gas emissions (i.e., mitigation)?

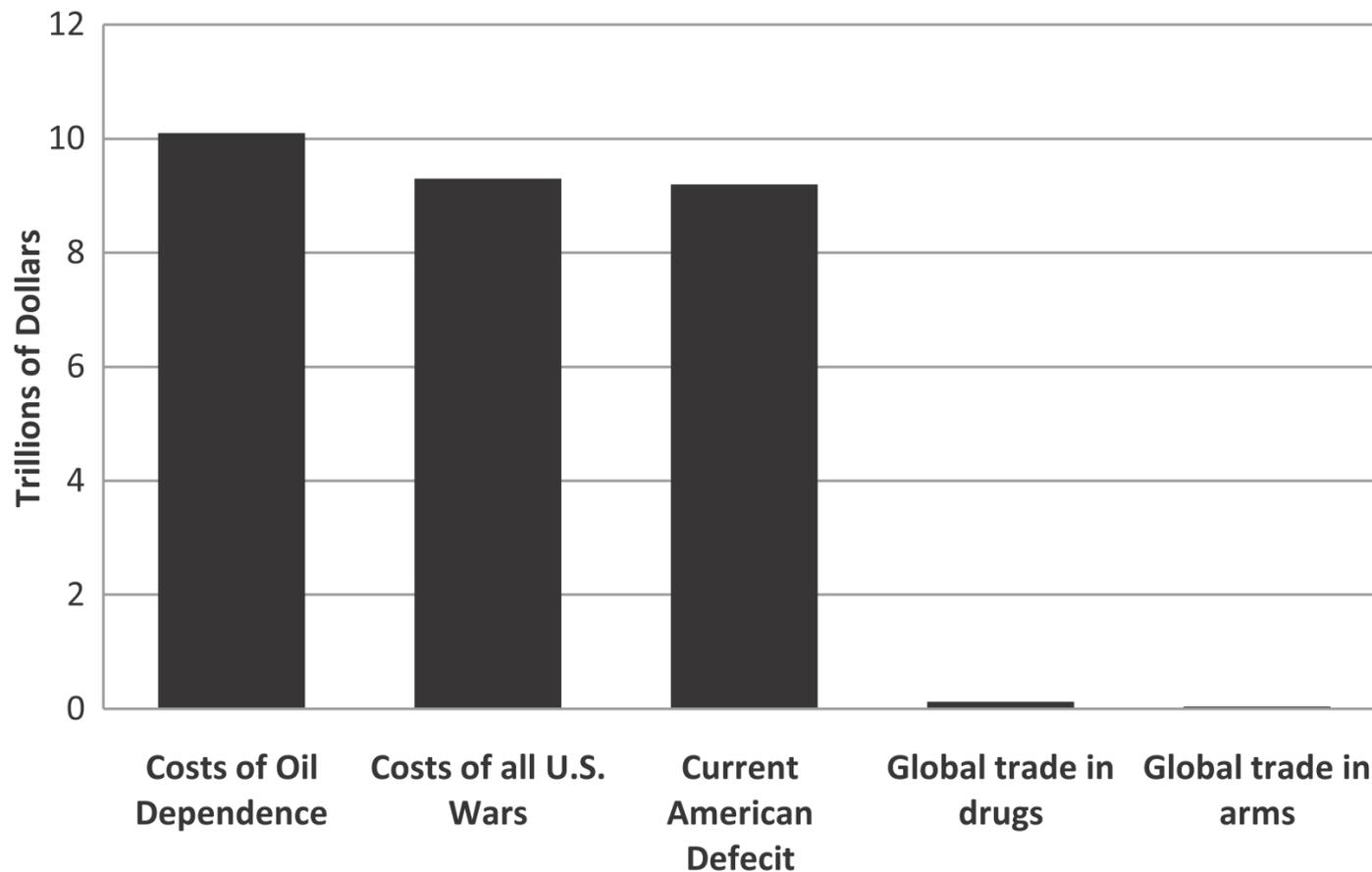


Fig. 4. Estimated direct economic costs of oil dependence for the United States, 1970–2004, compared to other costs. Source: [Greene and Ahmad, 2005](#). Figures updated to \$2007.

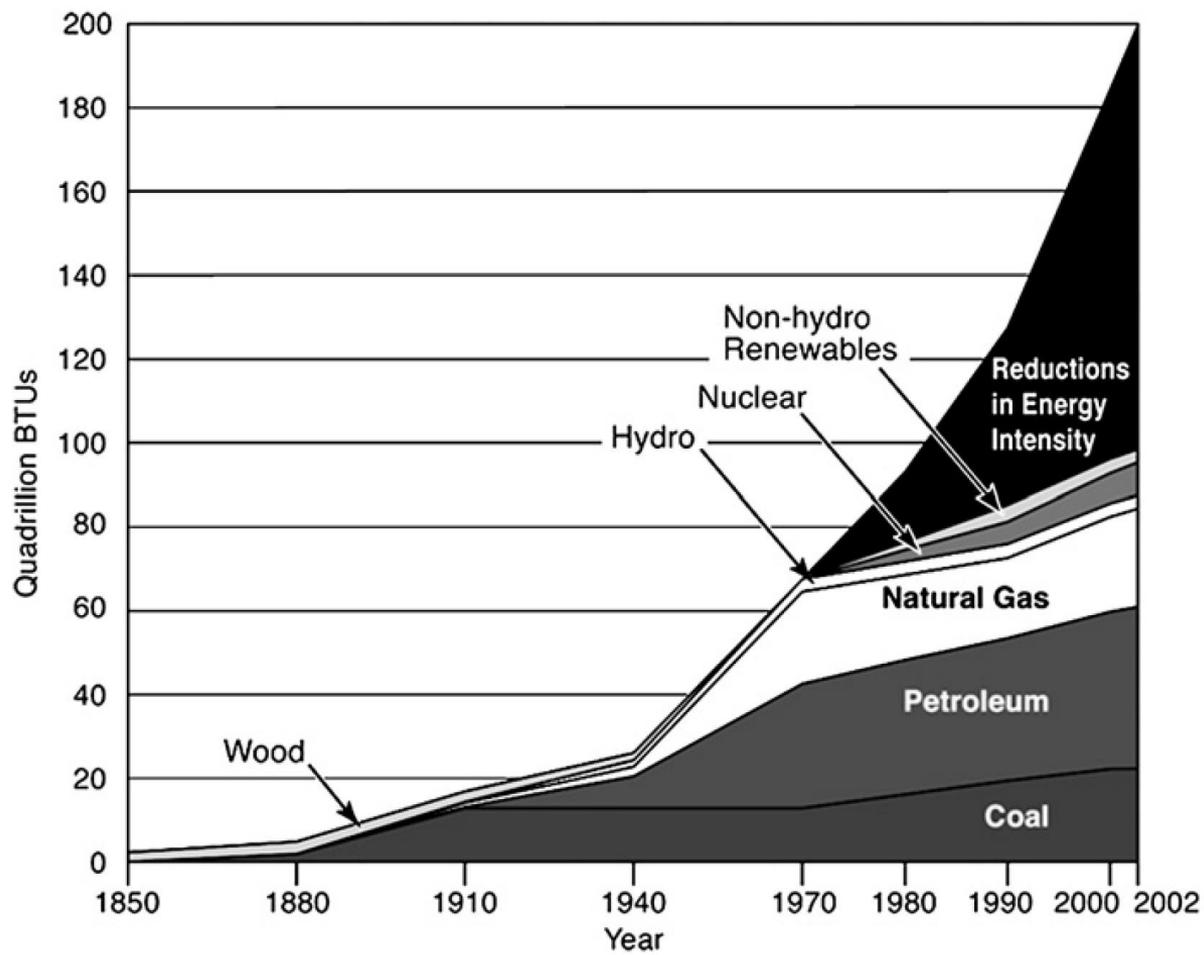


Fig. 5. Amount of energy saved from energy efficiency improvements in the United States, 1970–2002.

Table 4

Summary of mean ratings and rankings cross all dimensions of energy security (in order of importance).

Summary of ratings (<i>n</i> = 427)	
Providing available and clean water	4.83
Conducting research and development on new and innovative energy technologies	4.83
Minimizing air pollution	4.75
Minimizing the destruction of forests and the degradation of land and soil	4.73
Reducing greenhouse gas emissions (i.e., mitigation)	4.65
Informing consumers and promote social and community education about energy issues	4.56
Minimizing the impact of climate change (i.e., adaptation)	4.56
Assuring equitable access to energy services to all of its citizens	4.53
Lowering energy intensity (unit of energy required per unit of economic output)	4.49
Ensuring transparency and participation in energy permitting, siting, and decision-making	4.47
Having stable, predictable, and clear price signals	4.34
Promoting trade in energy products, technologies, and exports	4.19
Having a secure supply of coal, gas, oil and/or uranium	4.14
Having affordably priced energy services	4.10
Minimizing depletion of domestically available energy fuels	4.08
Having small-scale, decentralized energy systems	3.97
Summary of rankings (<i>n</i> = 427)	

Table 5
Mean energy security ratings broken down by occupation.

Energy security dimension	Private sector (<i>n</i> = 111)	Government (<i>n</i> = 81)	University (<i>n</i> = 162)	Non-profit (<i>n</i> = 64)	Intergovernmental (<i>n</i> = 13)
Having a secure supply of coal, gas, oil and/or uranium	4.22	3.92	4.00	4.51	4.64
Promoting trade in energy products, technologies, and exports	4.43	3.97	4.21	4.23	4.64
Minimizing depletion of domestically available energy fuels	4.19	4.10	3.78	4.15	3.73
Having stable, predictable, and clear price signals	4.44	4.24	4.39	4.34	4.45
Having affordably priced energy services	4.16	4.01	4.08	4.16	4.45
Having small-scale, decentralized energy systems	3.96	3.87	4.15	4.09	3.60
Having low energy intensity (unit of energy required per unit of economic output)	4.49	4.45	4.61	4.46	4.55
Conducting research and development on new and innovative energy technologies	4.85	4.80	4.94	4.73	5.00
Assuring equitable access to energy services to all of its citizens	4.38	4.58	4.67	4.55	4.55
Ensuring transparency and participation in energy permitting, siting, and decision-making	4.39	4.44	4.67	4.51	4.45
Informing consumers and promote social and community education about energy issues	4.46	4.55	4.72	4.56	4.55
Minimizing the destruction of forests and the degradation of land and soil	4.68	4.74	4.87	4.73	4.18
Providing available and clean water	4.81	4.79	4.89	4.90	4.73
Minimizing air pollution	4.66	4.74	4.85	4.82	4.64
Minimizing the impact of climate change (i.e., adaptation)	4.40	4.60	4.74	4.58	4.27
Reducing greenhouse gas emissions (i.e., mitigation)	4.48	4.68	4.85	4.68	4.55

Note: number (*n*) total equals more than 427 because some respondents selected more than one occupational category.

Table 6

Mean energy security ratings broken down by age.

Energy security dimension	18–25 (<i>n</i> = 43)	26–35 (<i>n</i> = 128)	36–45 (<i>n</i> = 68)	46–55 (<i>n</i> = 73)	55+ (<i>n</i> = 111)
Having a secure supply of coal, gas, oil and/or uranium	4.22	3.81	4.23	4.37	4.25
Promoting trade in energy products, technologies, and exports	4.33	4.13	4.05	4.27	4.22
Minimizing depletion of domestically available energy fuels	4.25	3.99	4.16	4.00	4.11
Having stable, predictable, and clear price signals	4.39	4.09	4.29	4.34	4.59
Having affordably priced energy services	4.22	4.07	4.08	4.10	4.10
Having small-scale, decentralized energy systems	3.82	3.87	3.95	4.03	4.09
Having low energy intensity (unit of energy required per unit of economic output)	4.44	4.45	4.61	4.43	4.51
Conducting research and development on new and innovative energy technologies	4.92	4.76	4.81	4.85	4.86
Assuring equitable access to energy services to all of its citizens	4.42	4.44	4.63	4.48	4.66
Ensuring transparency and participation in energy permitting, siting, and decision-making	4.44	4.40	4.37	4.37	4.68
Informing consumers and promote social and community education about energy issues	4.69	4.54	4.47	4.57	4.57
Minimizing the destruction of forests and the degradation of land and soil	4.89	4.68	4.69	4.84	4.67
Providing available and clean water	4.89	4.73	4.84	4.84	4.90
Minimizing air pollution	4.78	4.69	4.76	4.74	4.81
Minimizing the impact of climate change (i.e., adaptation)	4.72	4.50	4.61	4.58	4.50
Reducing greenhouse gas emissions (i.e., mitigation)	4.81	4.63	4.68	4.58	4.65
Having a secure supply of coal, gas, oil and/or uranium	4.22	3.81	4.23	4.37	4.25

Table 7

Mean energy security ratings broken down by gender.

Energy security dimension	Female (<i>n</i> = 181)	Male (<i>n</i> = 246)
Having a secure supply of coal, gas, oil and/or uranium	4.07	4.18
Promoting trade in energy products, technologies, and exports	4.19	4.18
Minimizing depletion of domestically available energy fuels	4.36	3.86
Having stable, predictable, and clear price signals	4.36	4.32
Having affordably priced energy services	4.32	3.93
Having small-scale, decentralized energy systems	4.15	3.83
Having low energy intensity (unit of energy required per unit of economic output)	4.52	4.46
Conducting research and development on new and innovative energy technologies	4.89	4.78
Assuring equitable access to energy services to all of its citizens	4.68	4.42
Ensuring transparency and participation in energy permitting, siting, and decision-making	4.57	4.39
Informing consumers and promote social and community education about energy issues	4.71	4.44
Minimizing the destruction of forests and the degradation of land and soil	4.86	4.63
Providing available and clean water	4.88	4.79
Minimizing air pollution	4.82	4.69
Minimizing the impact of climate change (i.e., adaptation)	4.66	4.48
Reducing greenhouse gas emissions (i.e., mitigation)	4.68	4.62
Having a secure supply of coal, gas, oil and/or uranium	4.07	4.18

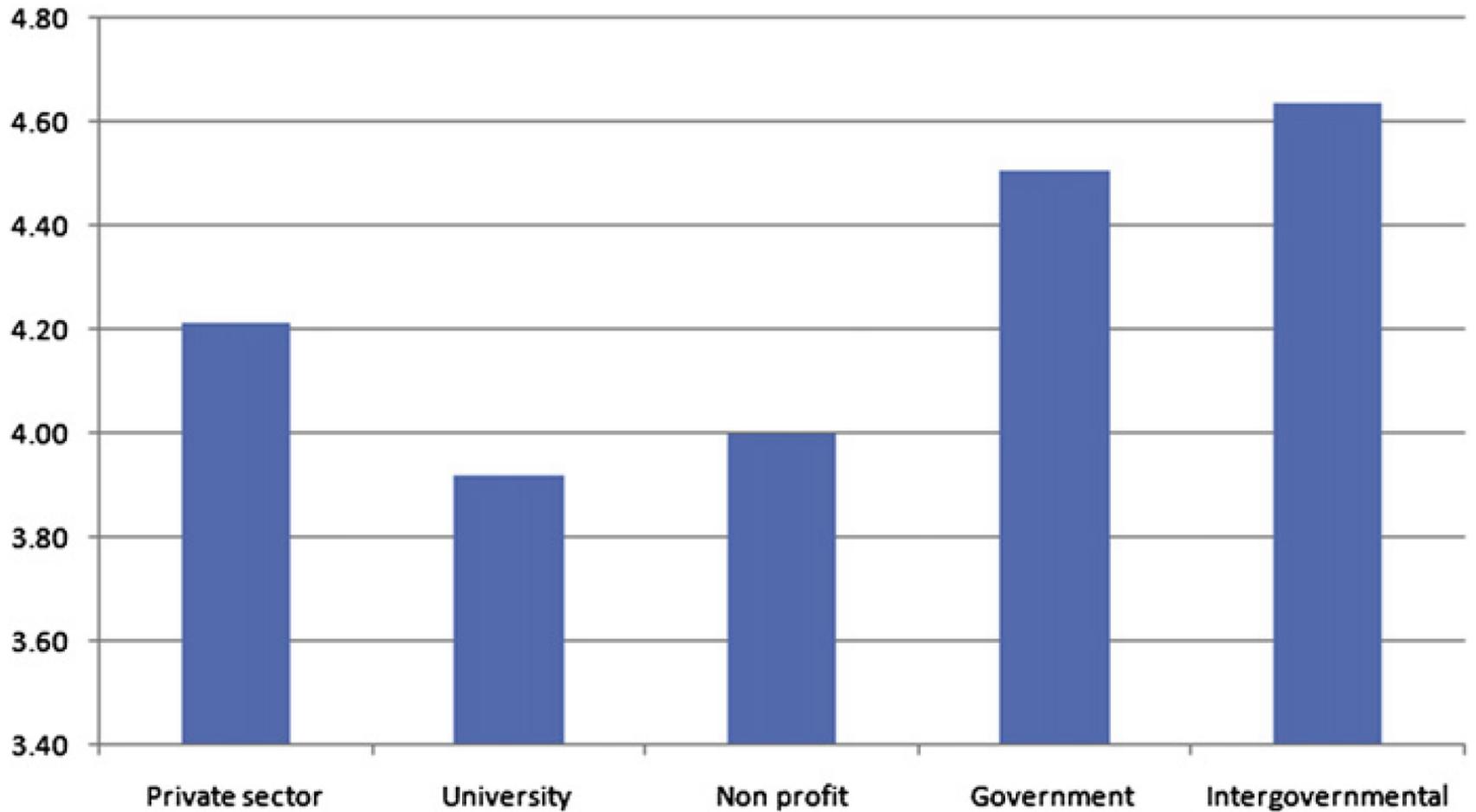


Fig. 6. Average rating for security of supply by occupation.

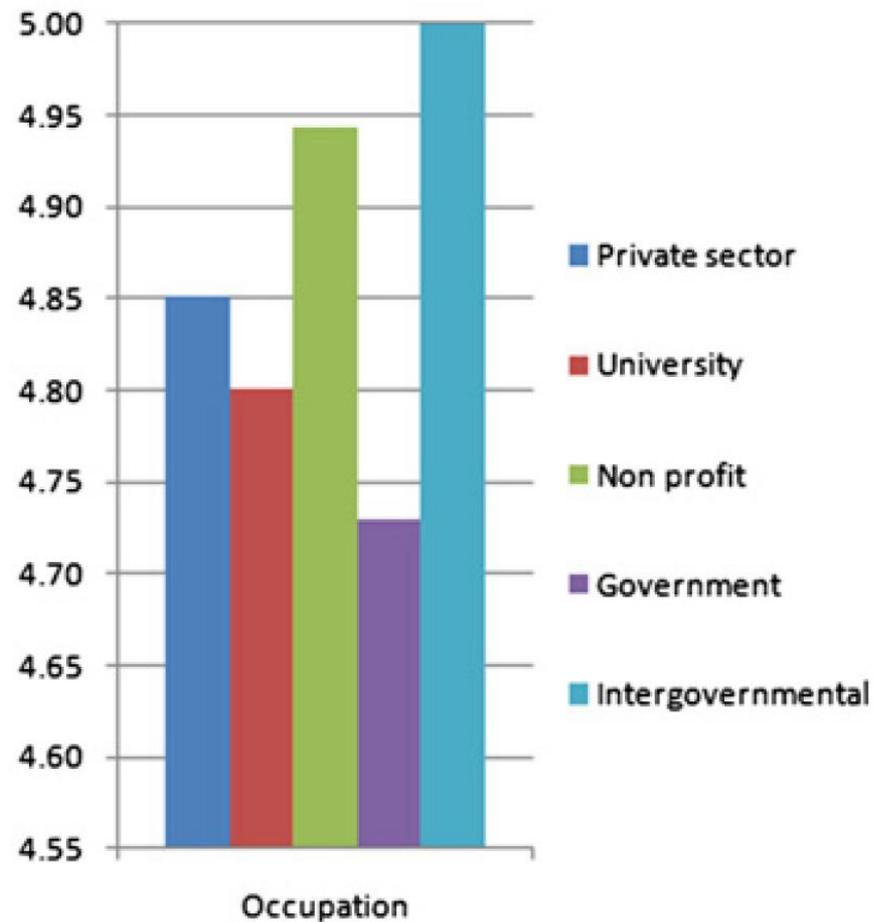
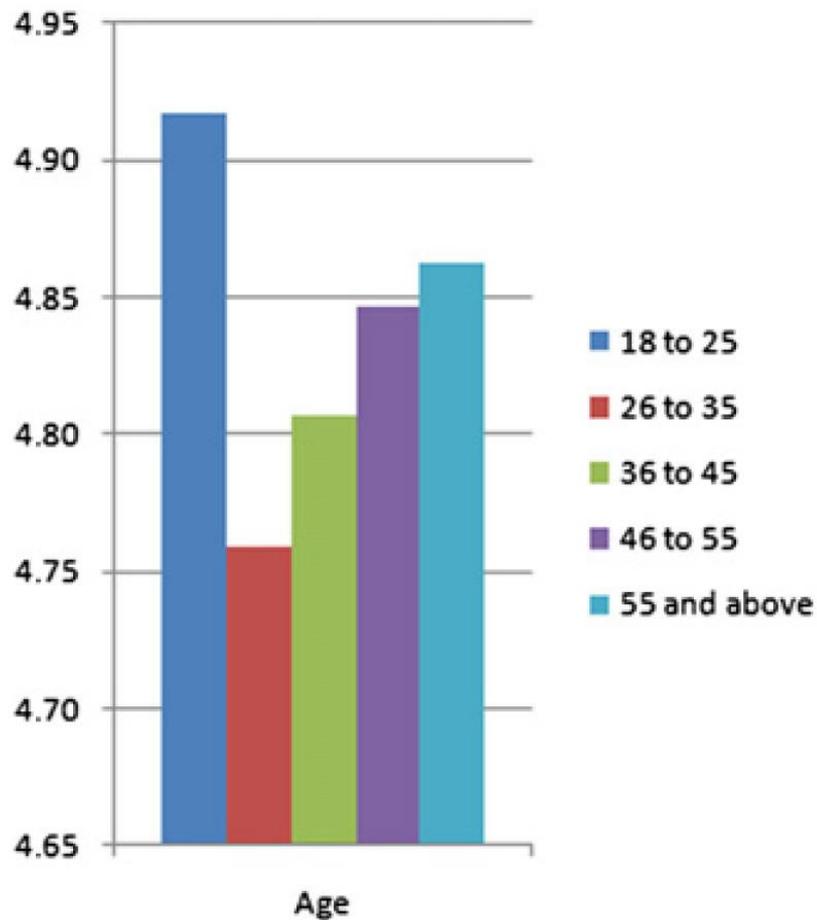


Fig. 8. Ratings for energy research by age and occupation.

Table 9

Rated energy security dimensions by private sector participants.

Dimension	Mean rating
Conducting research	4.85
Water	4.81
Destruction of forests and land	4.68
Air pollution	4.66
Energy efficiency	4.49
Climate change mitigation	4.48
Information and education	4.46
Price stability	4.44
Trade	4.43
Climate change adaptation	4.40
Transparency and participation	4.39
Equitable access	4.38
Security of supply	4.22
Minimizing depletion	4.19
Affordability	4.16
Decentralization	3.96

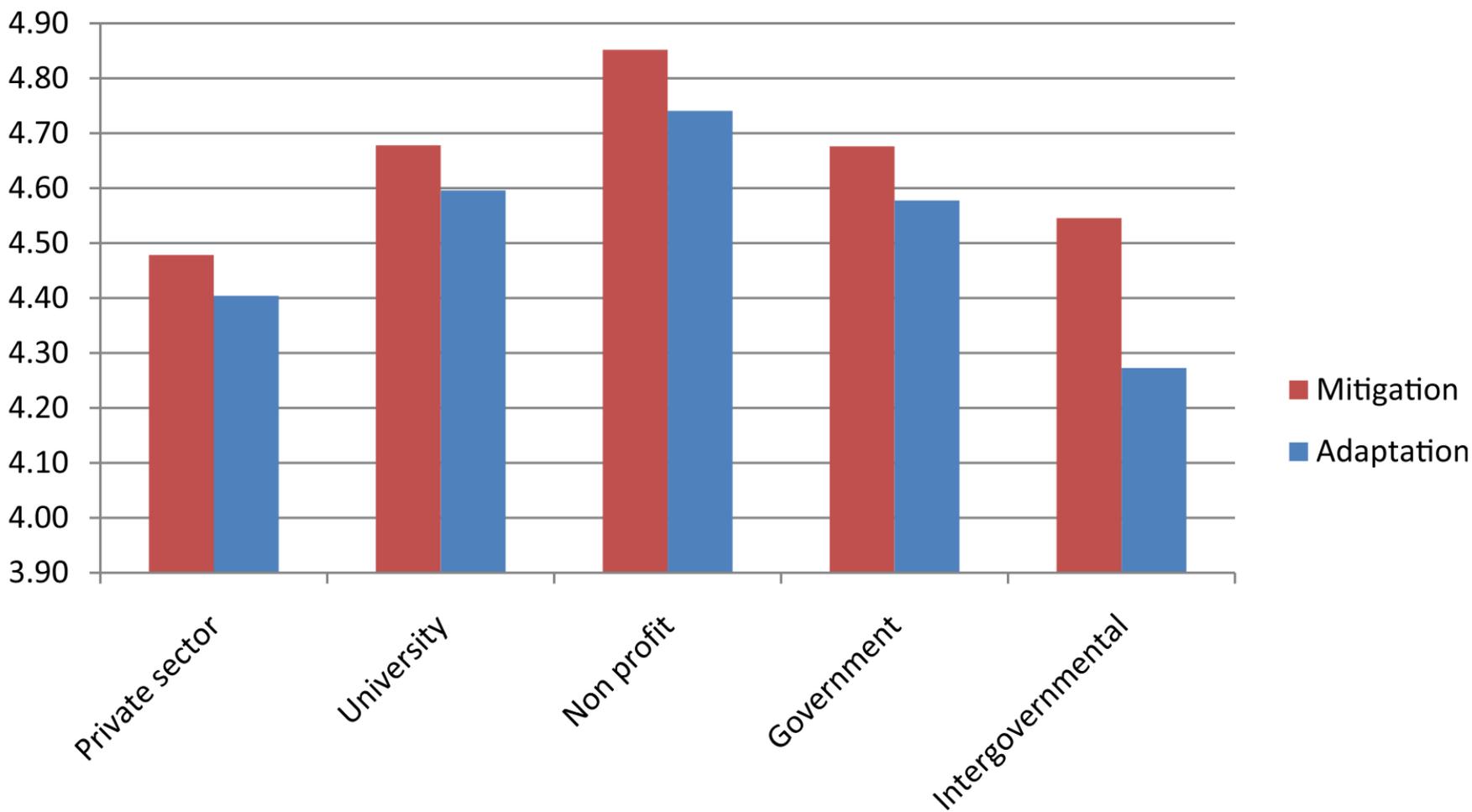


Fig. 10. Climate change mitigation and adaptation ratings broken down by occupation. ¹⁵³

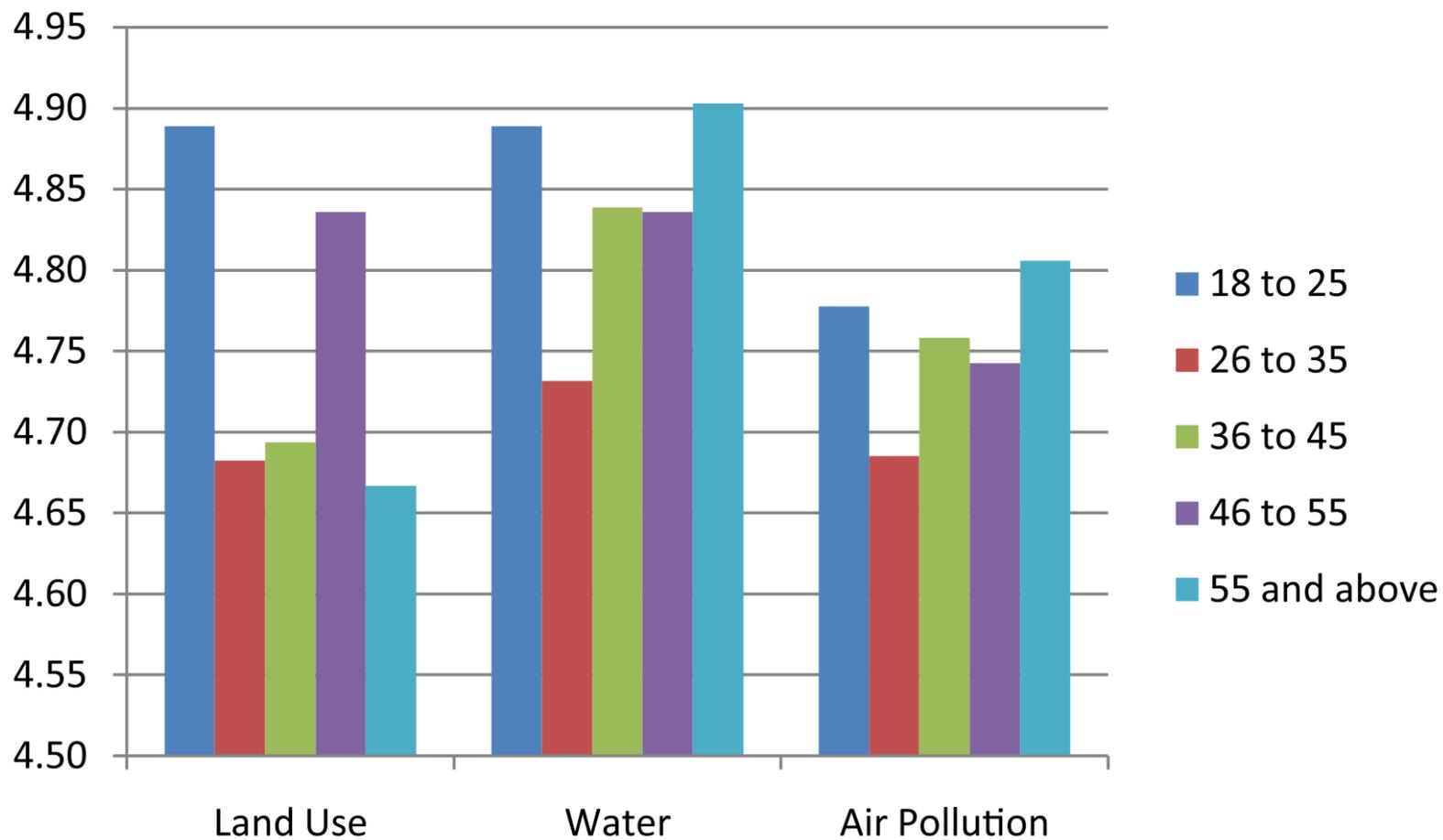


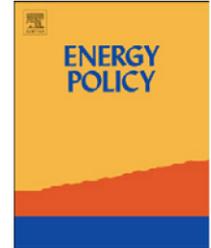
Fig. 9. Energy security ratings for destruction of forests and land, water, and air pollution by age group.



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The uniqueness of the energy security, justice, and governance problem[☆]

Andreas Goldthau^{a,*}, Benjamin K. Sovacool^b

^a Central European University, Budapest, Hungary

^b Institute for Energy and the Environment, Vermont Law School, USA

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ABSTRACT

This article argues that among all policy fields exhibiting externalities of a global scale, energy stands out on four dimensions: vertical complexity, horizontal complexity, higher entailed costs, and stronger path dependency. These structural attributes are at odds with contemporary key challenges of energy security, energy justice, and low carbon energy transition. With regard to the latter, energy governance challenges occur related to unclear levels of authority and weak resilience. This has implications for energy scholarship, specifically relating to the political economy of energy transitions, discussions about common pool resources, systems analysis, and other neighboring disciplines.

Key energy challenges:

- Energy security
- Energy justice
- Low carbon transition

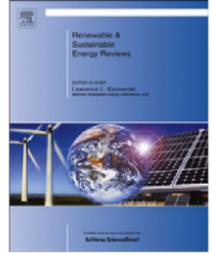


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Renewable and Sustainable Energy Reviews

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Assessing energy security performance in the Asia Pacific, 1990–2010

Benjamin K. Sovacool*

Vermont Law School, Institute for Energy & the Environment, PO Box 96, 164 Chelsea Street, South Royalton, VT 05068-0444, United States

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ABSTRACT

Based on three years of research involving a **literature review, interviews, surveys,** and an **international workshop,** this study first conceptualizes energy security as consisting of the interconnected factors of **availability, affordability, efficiency, sustainability,** and **governance.** It then matches these factors with **20 metrics** comprising an **energy security index,** tracking and scoring performance across **18 countries** from **1990 to 2010.** It lastly offers **two case studies** of **Malaysia** (most improved energy security over time) and **Myanmar** (worst improved) to provide context to the index's results before offering conclusions for scholars, analysts, and practitioners.

A B S T R A C T

Based on three years of research involving a literature review, interviews, surveys, and an international workshop, this study first conceptualizes energy security as consisting of the interconnected factors of availability, affordability, efficiency, sustainability, and governance. It then matches these factors with 20 metrics comprising an energy security index, tracking and scoring performance across 18 countries from 1990 to 2010. It lastly offers two case studies of Malaysia (most improved energy security over time) and Myanmar (worst improved) to provide context to the index's results before offering conclusions for scholars, analysts, and practitioners.

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Therefore, the author began by selecting eighteen countries to be assessed by an energy security index. The author chose the United States and the European Union (as its own entity) because they are the two of the world's most advanced energy producers and consumers, and serve as useful benchmarks; China, India, Japan, and South Korea because they are Asia's four largest energy consumers; and the ten countries comprising the Association of Southeast Asian Nations (ASEAN) (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam) because they have rapidly developing economies. Australia and New Zealand were finally selected because they represent a diverse mix of energy importers and exporters and are also close in proximity to ASEAN.

Dimensions and components of Energy Security:

Availability

- ✓ Security of supply
- ✓ Production
- ✓ Dependency
- ✓ Diversification

Affordability

- ✓ Stability
- ✓ Access
- ✓ Equity
- ✓ Affordability

Dimensions and components of Energy Security:

☐ **Technology development & efficiency**

- ✓ Innovation & research
- ✓ Energy efficiency
- ✓ Safety & reliability
- ✓ Resilience

☐ **Environmental sustainability**

- ✓ Land use
- ✓ Water
- ✓ Climate change
- ✓ Pollution

Dimensions and components of Energy Security:

Regulation & governance

- ✓ Governance
- ✓ Trade & connectivity
- ✓ Competition
- ✓ Information

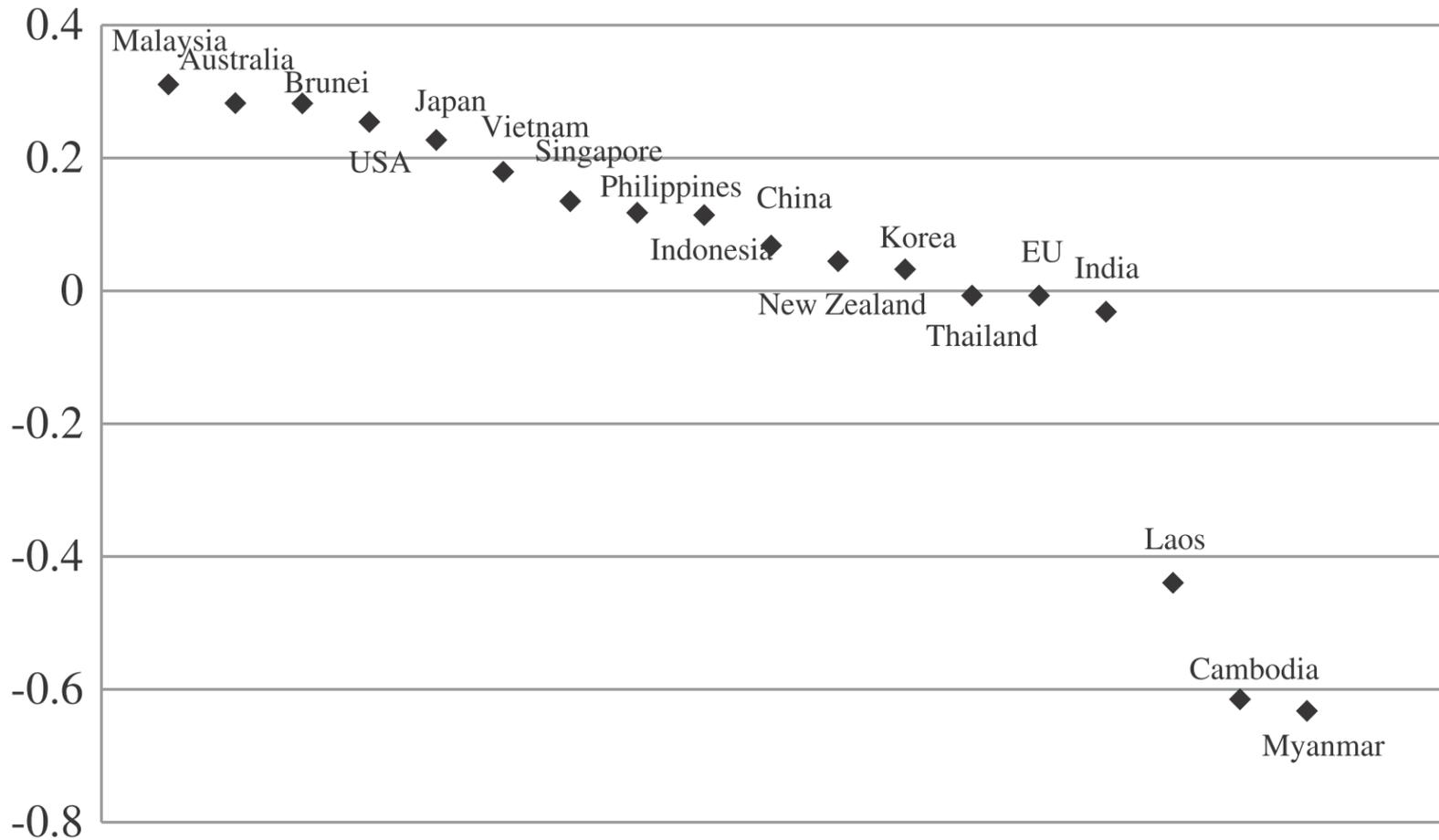


Fig. 1. Energy security improvement for eighteen countries (% Change from 1990 to 2010).

Table 4**Oil reserves** for Southeast Asia.

Country	Total proven reserves (billion barrels).
Cambodia	0
Brunei	1.2
Indonesia	4.37
Laos	0
Malaysia	5.36
Myanmar	0.20
Philippines	0.14
Singapore	0
Thailand	0.46
Vietnam	0.6
Total	12.33

Table 5**Natural gas reserves** for Southeast Asia.

Country	Proven reserves (trillion cubic feet)	Possible reserves (trillion cubic feet)	Probable reserves (trillion cubic feet)	Total (trillion cubic feet)
Cambodia	0	0	0	0
Brunei	8	4	0	12
Indonesia	90	42	34	166
Laos	0	0	0	0
Malaysia	58	28	0	86
Myanmar	21	17	10	48
Philippines	3	1	1	5
Singapore	0	0	0	0
Thailand	12	9	11	32
Vietnam	5	11	9	25
Total	197	112	65	374

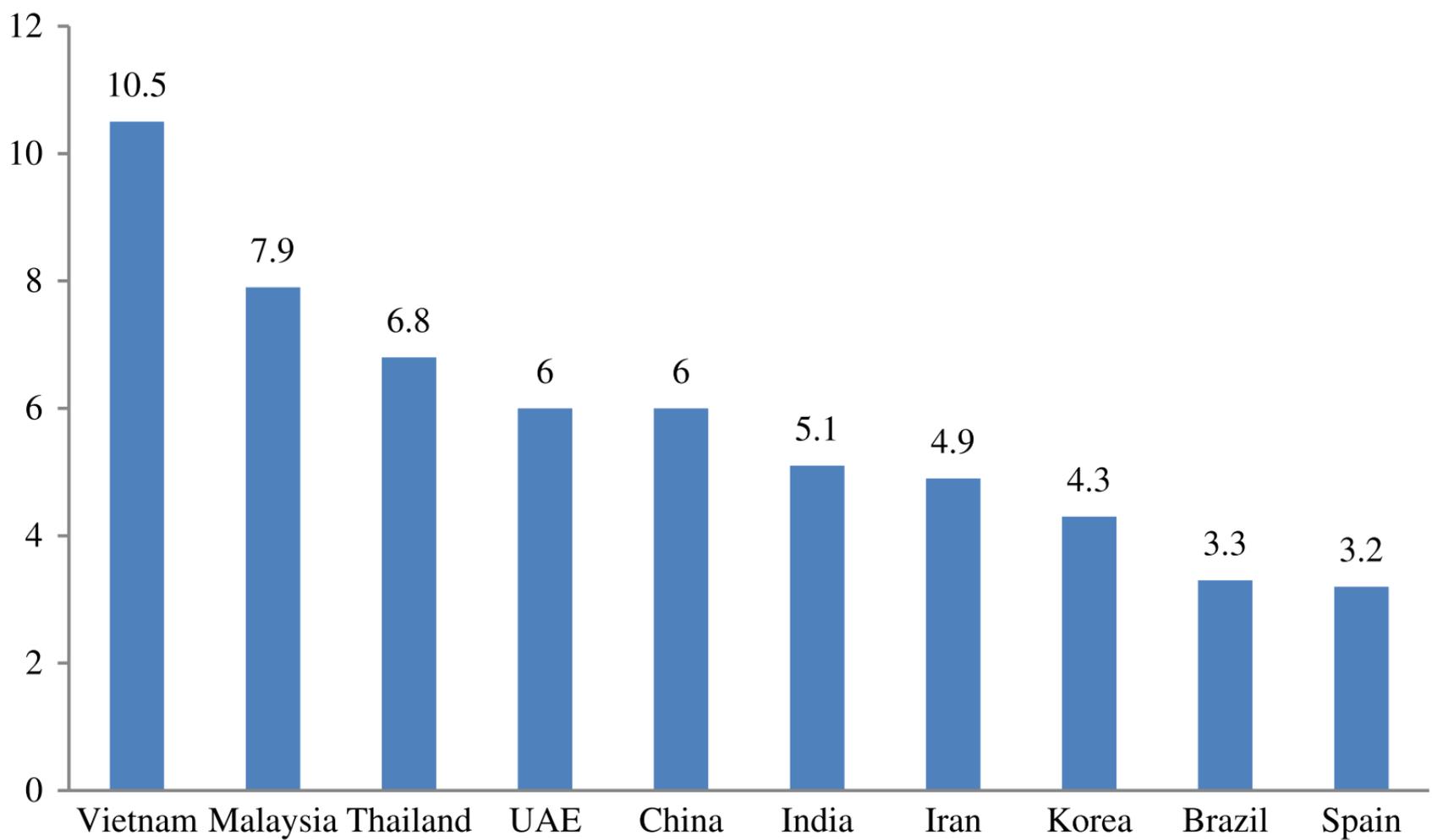


Fig. 2. Average annual growth rates in carbon dioxide emissions for the top 10 countries, 1990 to 2006 (166%).

Table 8

Carbon equivalent emissions by country for 2000 (Million metric tons of carbon).

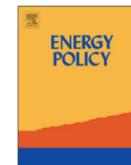
Country	Emissions from non-LULUCF sources		Emissions from LULUCF sources	Total GHG emissions	
	MtC	Rank	MtC	MtC	Rank
United States	1891	1	– 110	1781	1
China	1348	2	– 13	1335	2
European Union-25	1290	3	– 6	1284	3
Indonesia	137	15	700	837	4
Brazil	232	8	375	607	5
Russia	523	4	15	538	6
India	514	5	– 11	503	7
Japan	359	6	1	361	8
Germany	276	7	0	276	9
Malaysia	45	33	191	236	10
Canada	186	9	18	203	11
United Kingdom	178	10	0	178	12
Mexico	140	14	26	166	13
Italy	145	11	– 1	144	14
South Korea	142	12	0	143	15
Myanmar	23	48	116	139	16
France	140	13	– 2	138	17
Australia	134	16	1	135	18
Iran	131	18	2	133	19
Ukraine	132	17	0	132	20



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Energy policymaking in Denmark: Implications for global energy security and sustainability

Benjamin K. Sovacool^{a,b,*}^a Vermont Law School, Institute for Energy and the Environment, PO Box 96, 164 Chelsea Street, South Royalton, VT 05068-0444, United States^b School of Business and Social Sciences, Aarhus University, AU-Herning, Birk Centerpark 15, DK-7400 Herning, Denmark

H I G H L I G H T S

- Denmark is arguably the most energy secure and sustainable country in the OECD.
- This study explores the core of Denmark's successful approach.
- Denmark phased out oil-fired power plants in less than five years.
- It also implemented a progressive moratorium on coal-fired power plants.

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A B S T R A C T

Denmark is arguably the **most energy secure** and **sustainable** country in the Organization of Economic Cooperation and Development (OECD). The country has reduced its **dependence on foreign sources of energy to zero** and become **self-sufficient in its own energy production and use**, offering important lessons for other nations around the world. This study explores the core of Denmark's successful approach: a **commitment to energy efficiency**, prolonged **taxes on energy fuels, electricity, and carbon dioxide**, and **incentives for combined heat and power (CHP)** and wind turbines. Through these commitments, the study shows how Denmark transitioned from being **almost 100 percent dependent on imported fuels such as oil and coal for their power plants in 1970** to becoming a **net exporter of fuels and electricity today**. The country leads the world in terms of **exportation of wind energy technology**, with a hold on roughly **one-third of the world market for wind turbines**. It was able to **phase out the use of virtually all oil-fired power plants in less than five years** and implemented a progressive moratorium on future coal-fired power plants in the 1990s. Their most recent strategy seeks to achieve **30 percent of total energy supply from renewable energy by 2025**.

A B S T R A C T

Denmark is arguably the most energy secure and sustainable country in the Organization of Economic Cooperation and Development (OECD). The country has reduced its dependence on foreign sources of energy to zero and become self-sufficient in its own energy production and use, offering important lessons for other nations around the world. This study explores the core of Denmark's successful approach: a commitment to energy efficiency, prolonged taxes on energy fuels, electricity, and carbon dioxide, and incentives for combined heat and power (CHP) and wind turbines. Through these commitments, the study shows how Denmark transitioned from being almost 100 percent dependent on imported fuels such as oil and coal for their power plants in 1970 to becoming a net exporter of fuels and electricity today. The country leads the world in terms of exportation of wind energy technology, with a hold on roughly one-third of the world market for wind turbines. It was able to phase out the use of virtually all oil-fired power plants in less than five years and implemented a progressive moratorium on future coal-fired power plants in the 1990s. Their most recent strategy seeks to achieve 30 percent of total energy supply from renewable energy by 2025.

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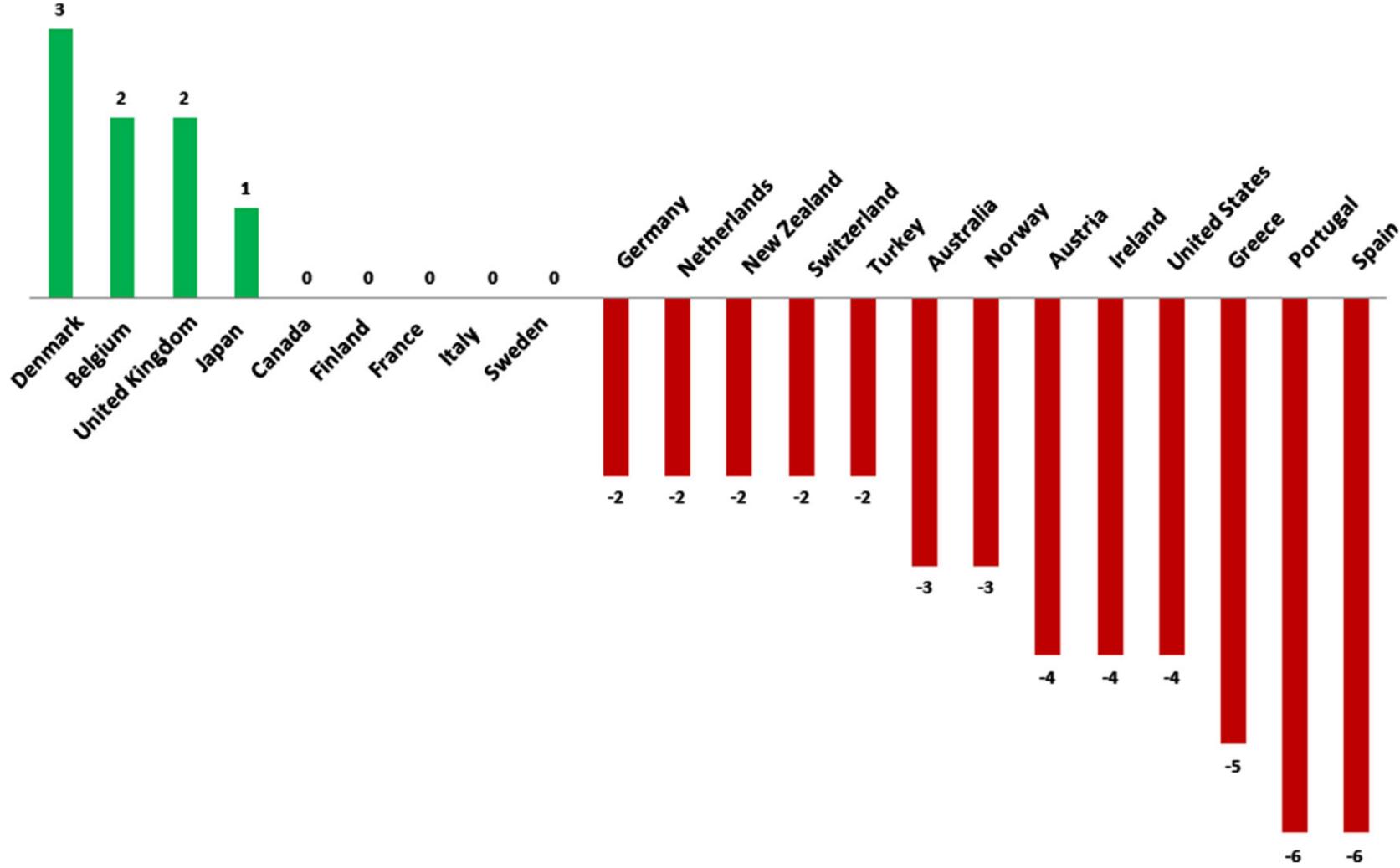


Fig. 1. Energy security performance among 22 OECD countries, from 1970 to 2007.

Table 1

Key energy statistics for Denmark, from 1980 to 2010.

Source: Danish Energy Authority

Energy intensity, gross energy consumption (TJ per DKK million GDP, 2000 prices)

Gross energy consumption per capita (GJ)

Degree of self-sufficiency (%)

Renewable energy—share of gross energy consumption (%)

Wind turbine capacity—share of total electricity capacity (%)

CHP production—share of total thermal electricity production (%)

CHP production—share of total district heating production (%)

Renewable energy—share of total domestic electricity supply (%)

CO₂ emissions per capita (tonnes)

CO₂ emissions per kW h electricity sold (gram CO₂ per kW h)

CO₂ emissions per GNP (tonnes per Million GDP)

Table 1

Key energy statistics for Denmark, from 1980 to 2010.

Source: Danish Energy Authority

	1980	1990	1995	2000	2005	2010
Energy intensity, gross energy consumption (TJ per DKK million GDP, 2000 prices)	0.998	0.818	0.748	0.649	0.618	0.591
Gross energy consumption per capita (GJ)	159	160	161	157	157	147
Degree of self-sufficiency (%)	5	52	78	139	155	121
Renewable energy—share of gross energy consumption (%)	2.9	6.1	7.0	9.8	14.7	20.2
Wind turbine capacity—share of total electricity capacity (%)	–	3.8	5.7	19.0	23.9	27.7
CHP production—share of total thermal electricity production (%)	18	37	40	56	64	61
CHP production—share of total district heating production (%)	39	59	74	82	82	77
Renewable energy—share of total domestic electricity supply (%)	0.0	2.0	5.9	15.3	17.8	33.1
CO ₂ emissions per capita (tonnes)	12.2	11.9	11.5	10.4	9.7	8.5
CO ₂ emissions per kW h electricity sold (gram CO ₂ per kW h)	1034	937	807	634	538	505
CO ₂ emissions per GNP (tonnes per Million GDP)	77	61	53	43	38	34

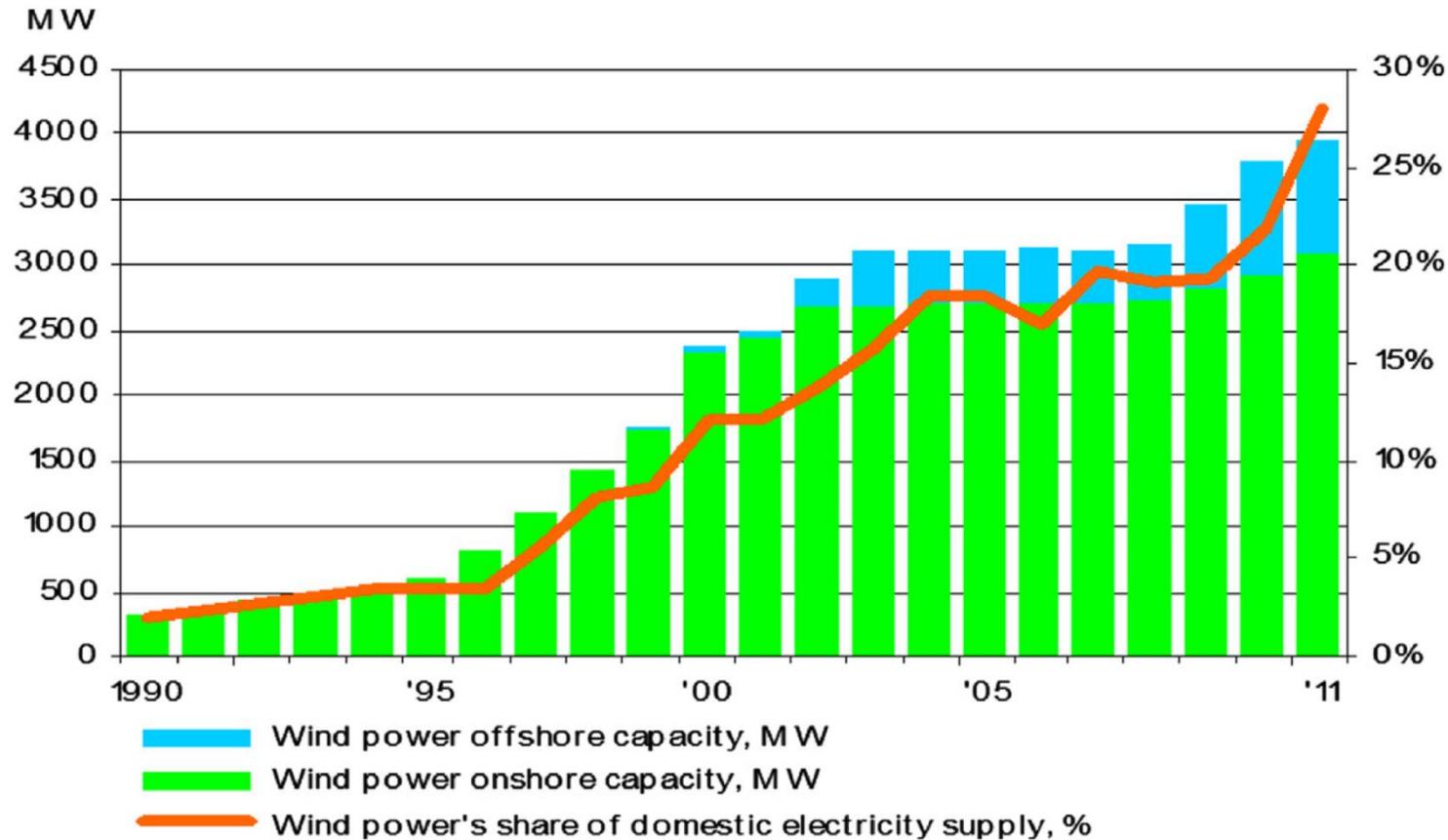


Fig. 2. Wind power capacity and share of domestic electricity supply in Denmark, 1990–2011.

Source: Danish Energy Authority.

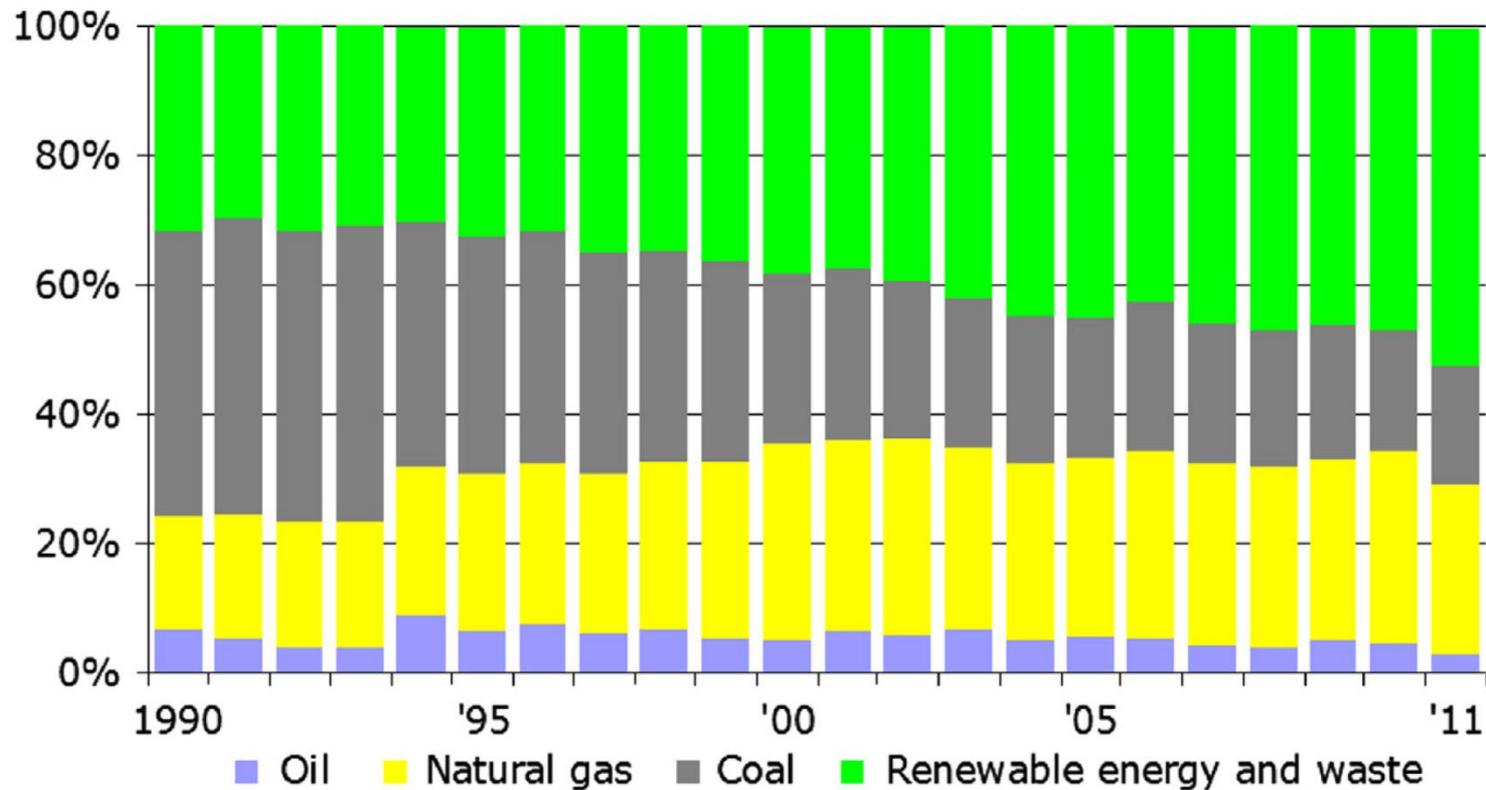


Fig. 3. Fuel composition for CHP facilities in Denmark, 1990–2011.

Source: Danish Energy Authority.

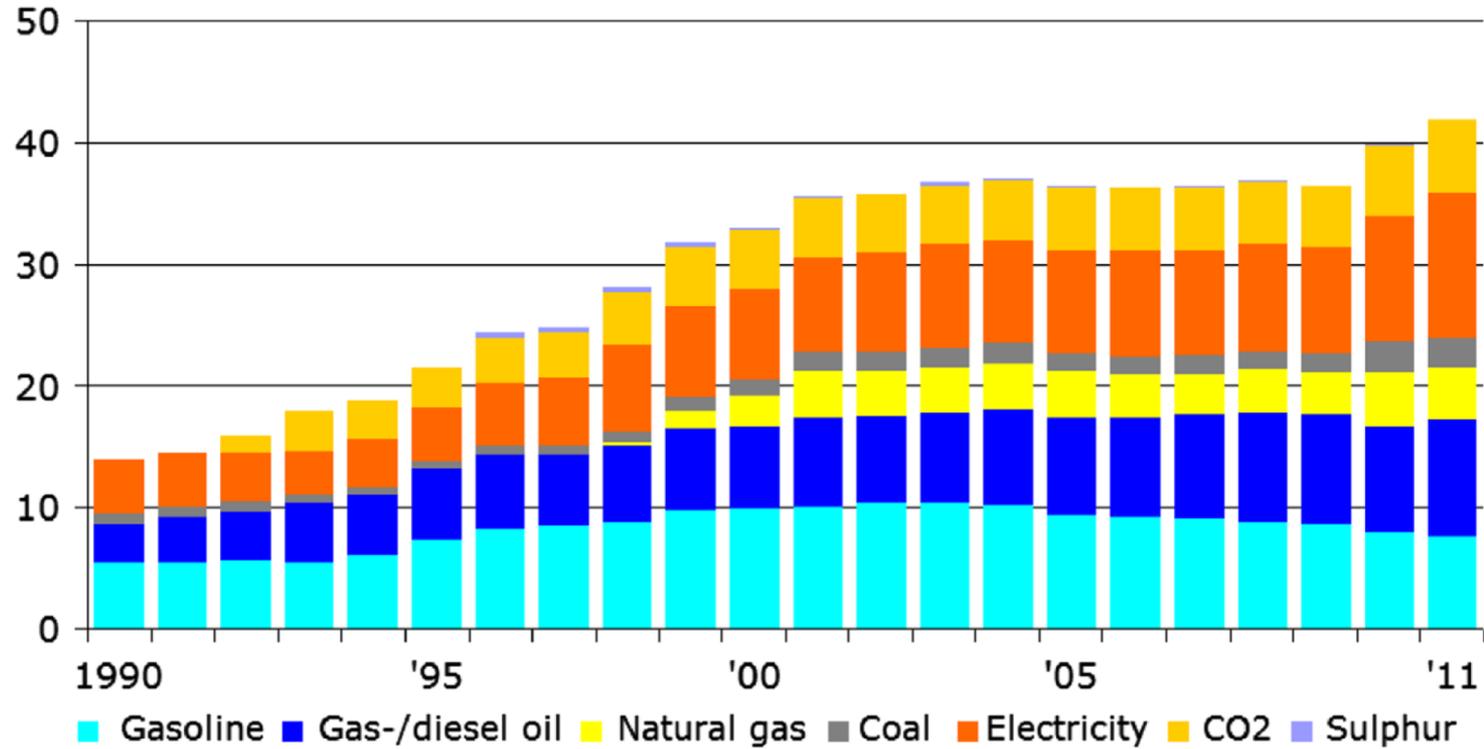


Fig. 5. Revenues from energy, CO₂ and sulfur taxes, billion DKK, 1990–2011 (in current prices). *Note:* as of June 2013, 1 DKK=US\$0.176. *Source:* Danish Energy Authority.

Fogh Rasmussen announced a long-term target of “100 percent independency of fossil fuels and nuclear power”, later presented as a national “Energy Plan of 2006” (Lund and Mathiesen, 2009). This ambitious target was later formalized into a Danish Society of Engineers (IDA) energy strategy called the “IDA Energy Plan” consisting of four prongs:

- **Reduce energy demand** in the long term, including a reduction in space heating demand in buildings by 50 percent, fuel consumption in industry by 40 percent, and electricity demand by 50 percent.
- **Improve energy efficiency** by encouraging heat pumps and solar thermal water heaters for homes and fuel switching for CHP units away from gas, coal, and oil.
- **Expand renewable energy** so that 30 percent of national supply comes from renewables by 2025 and 100 percent by 2050 (more specific targets include doubling the amount of wind capacity and introducing 500 MW of wave power and 700 MW of solar PV power).
- **Promote intelligent energy systems** that can better balance supply and demand, reduce transmission losses, and utilize “smart grid” technologies (Sperling et al., 2011).

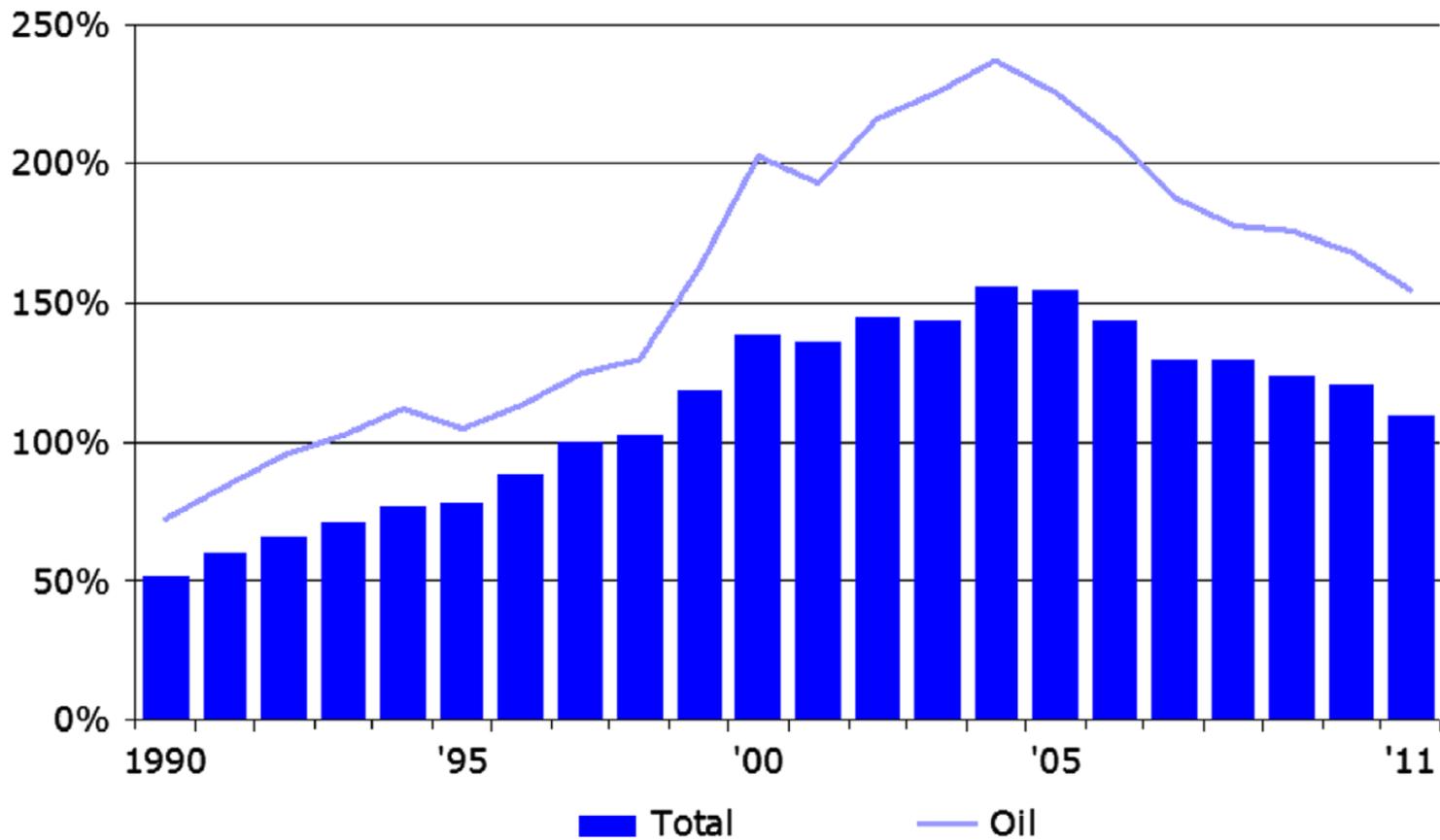


Fig. 6. Degree of energy self-sufficiency in Denmark, 1990–2011.
Source: Danish Energy Authority.

4.4. *Rising social opposition*

Though Danish attitudes towards wind energy remain largely positive compared to other countries (Pasqualetti, 2011), **larger wind turbines** and consolidation of **wind farms** among corporate actors has started to engender an increase in social protest and opposition, especially over larger turbines that obstruct environmental viewscapes and exclude **local cooperatives** and **farmers** from ownership and participation. As a result, one study found an “added pressure” against wind turbines for the reasons that they have become **too large and “visible”** for some Danes to approve (Möller, 2010). A second inquiry into attitudes towards wind power in Northern Jutland cautioned that **“ever-increasing turbine size** and **less local involvement** ... could ultimately lead to a decline in the popular acceptance of wind power” (Möller, 2006).¹⁷⁹

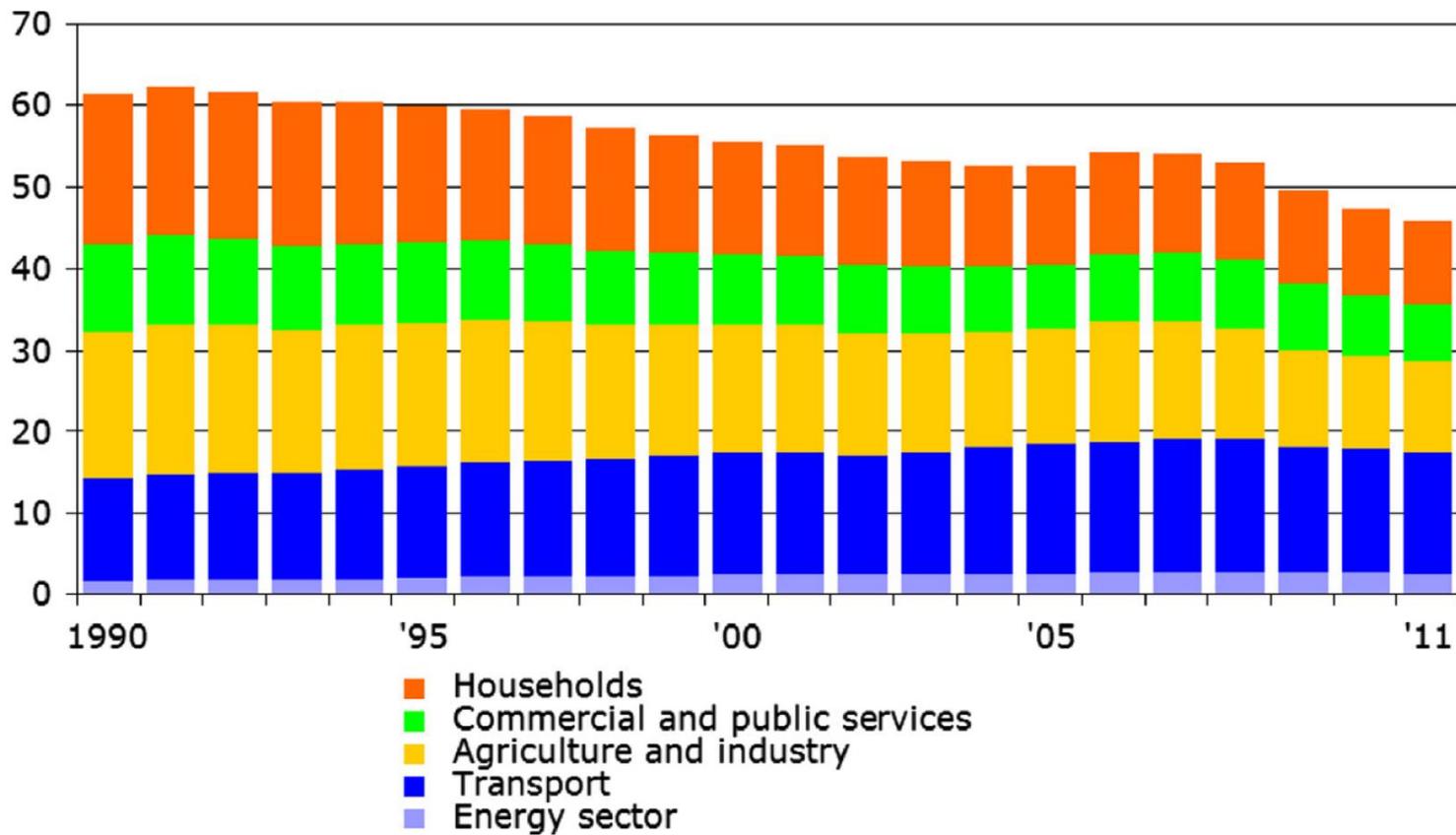


Fig. 8. CO₂ emissions in final energy consumption, 1990–2011 (million tons, climate adjusted).
 Source: Danish Energy Authority.

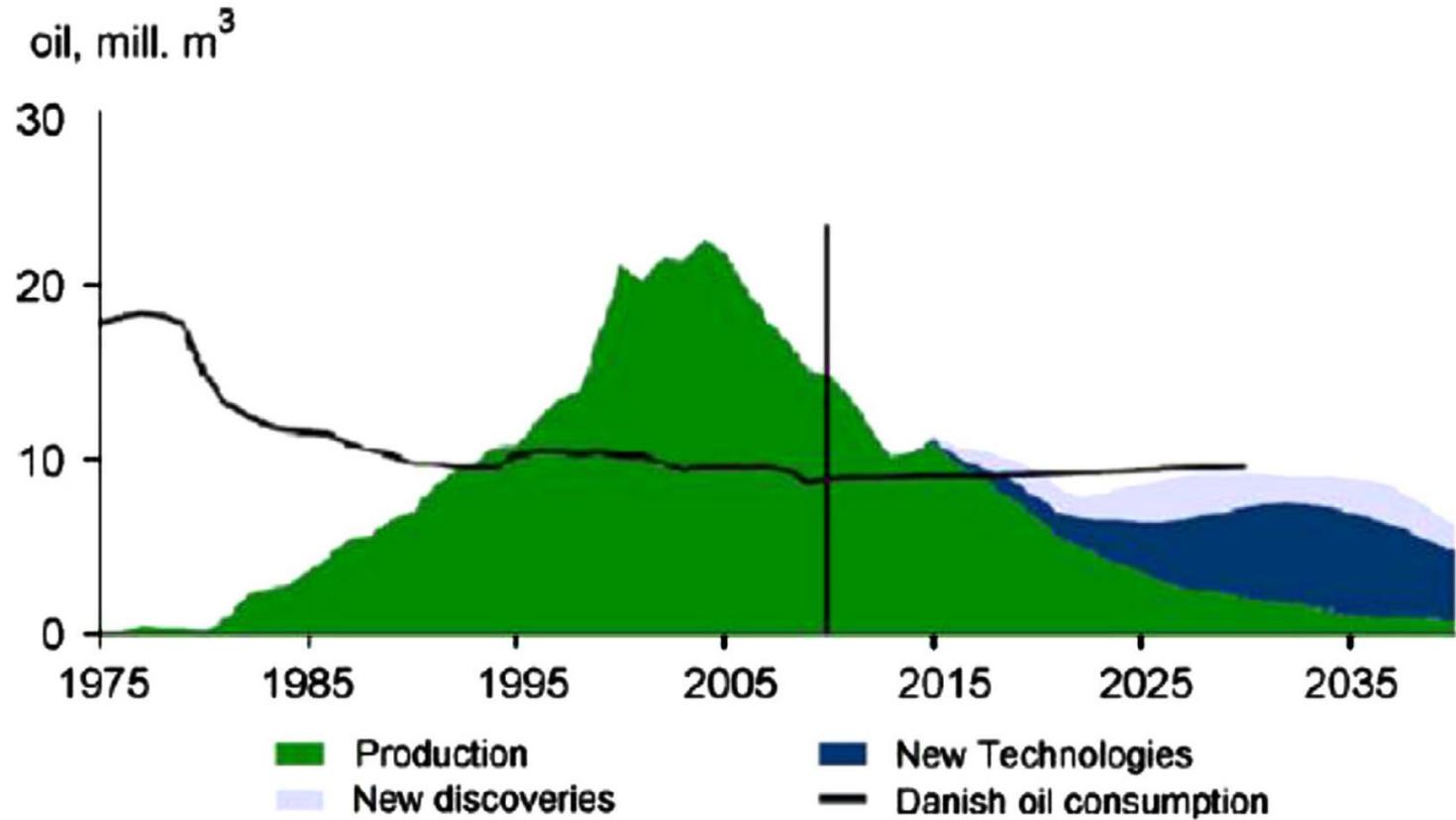


Fig. 9. Oil production in Denmark, from 1975 to 2040.
Source: Danish Energy Authority.



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Analysis

An international assessment of energy security performance

Benjamin K. Sovacool*

Vermont Law School, Institute for Energy & the Environment, P.O. Box 96, 164 Chelsea Street, South Royalton, VT 05068-0444, United States

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ABSTRACT

Energy security has in recent years grown as a salient policy and political issue. To better understand energy security and sustainability concerns, this study's main objective is to present an energy security index which measures national performance on energy security over time. Based on three years of research involving interviews, surveys, and an international workshop, this study conceptualizes energy security as consisting of the interconnected factors of availability, affordability, efficiency, sustainability, and governance. It then matches these factors with 20 metrics comprising an energy security index, measuring international performance across 18 countries from 1990 to 2010. It offers three case studies of Japan (top performer), Laos (middle performer), and Myanmar (worst performer) to provide context to the index's results. It then presents four conclusions. First, a majority of countries analyzed have regressed in terms of their energy security. Second, despite the near total deterioration of energy security, a great disparity exists between countries, with some clear leaders such as Japan. Third, tradeoffs exist within different components of energy security. Fourth, creating energy security is as much a matter of domestic policy from within as it is from foreign policy without.

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A B S T R A C T

Energy security has in recent years grown as a salient policy and political issue. To better understand energy security and sustainability concerns, this study's main objective is to present an energy security index which measures national performance on energy security over time. Based on three years of research involving interviews, surveys, and an international workshop, this study conceptualizes energy security as consisting of the interconnected factors of availability, affordability, efficiency, sustainability, and governance. It then matches these factors with 20 metrics comprising an energy security index, measuring international performance across 18 countries from 1990 to 2010. It offers three case studies of Japan (top performer), Laos (middle performer), and Myanmar (worst performer) to provide context to the index's results. It then presents four conclusions. First, a majority of countries analyzed have regressed in terms of their energy security. Second, despite the near total deterioration of energy security, a great disparity exists between countries, with some clear leaders such as Japan. Third, tradeoffs exist within different components of energy security. Fourth, creating energy security is as much a matter of domestic policy from within as it is from foreign policy without.

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Shortcomings of energy security index studies:

❑ **Topical focus**

- ✓ Industrial countries, e.g. EU, OECD, North America
- ✓ Sustainable development, energy poverty

❑ **Scope & coverage**

- ✓ Sector specific, e.g. electricity, oil, fossil fuels
- ✓ Geopolitics?
- ✓ Unbalanced or limited metrics

Shortcomings of energy security index studies:

❑ **Transparency**

- ✓ Aggregation ~ transparency
- ✓ Complex models
- ✓ Hidden/problematic assumptions
- ✓ *“Trojan horses ... dressed a certain way to get inside the gates of energy policymaking”*

❑ **Continuity**

- ✓ Snapshots
- ✓ Need to cover numbers of years

Dimensions & components of energy security:

☐ **Availability**

- ✓ Security of supply
- ✓ Production
- ✓ Dependency
- ✓ Diversification

☐ **Affordability**

- ✓ Stability
- ✓ Access
- ✓ Equity
- ✓ Affordability

Dimensions & components of energy security:

☐ **Technology development & efficiency**

- ✓ Innovation & research
- ✓ Energy efficiency
- ✓ Safety & reliability
- ✓ Resilience

☐ **Environmental sustainability**

- ✓ Land use
- ✓ Water
- ✓ Climate change
- ✓ Pollution

Dimensions & components of energy security:

□ **Regulation & governance**

- ✓ Governance
 - Worldwide governance ratings
- ✓ Trade & connectivity
- ✓ Competition
- ✓ Information

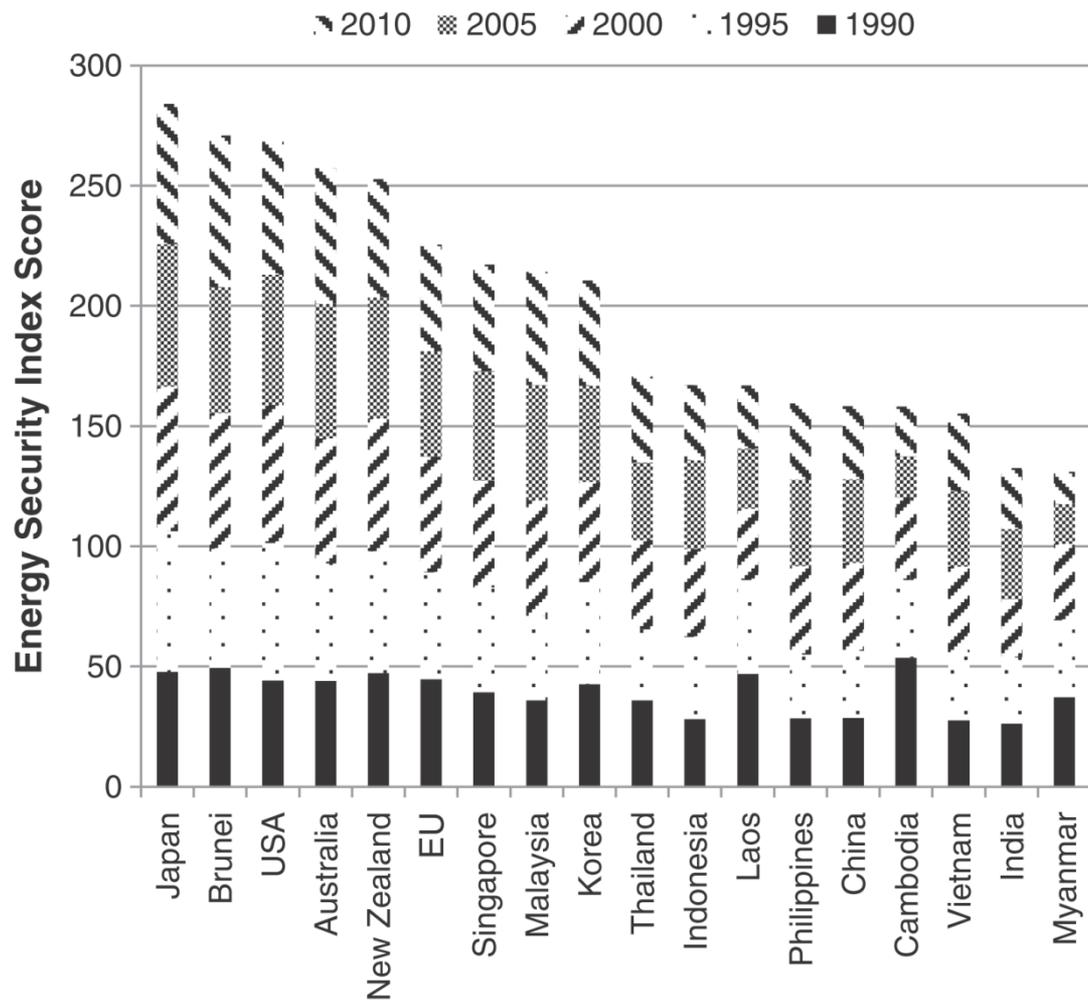


Fig. 1. Average energy security performance for eighteen countries.



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Understanding attitudes toward energy security: Results of a cross-national survey

Janelle Knox-Hayes^{a,*}, Marilyn A. Brown^a, Benjamin K. Sovacool^b, Yu Wang^a

^a School of Public Policy, Georgia Institute of Technology, Atlanta, GA, United States

^b Vermont Law School, United States

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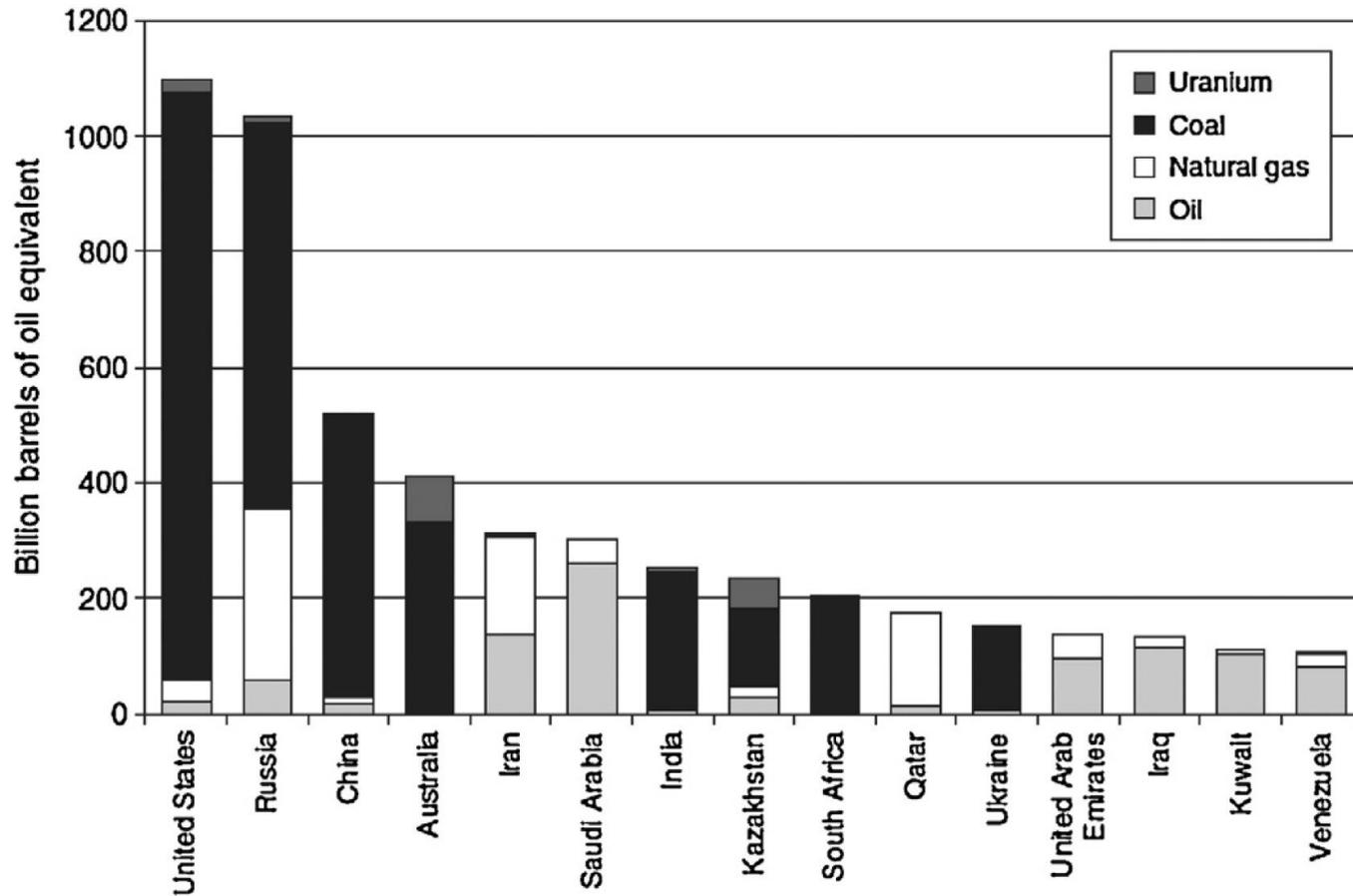
Security of supply

Energy sustainability

ABSTRACT

Energy security is embedded in a **complex system** encompassing factors that constitute the social environment in which individuals are immersed. Everything from education, to access to resources to policy and cultural values of particular places affects **perceptions and experiences** of energy security. This article examines the types of **energy security challenges that nations face** and characterizes the policy responses that are often used to address these challenges. Drawing from a **survey of energy consumers** in **Brazil, China, Germany, India, Kazakhstan, Japan, Papua New Guinea, Saudi Arabia, Singapore, and the United States**, we conduct a **cross-national comparison of energy security attitudes** as well as analyze each country's energy resources, consumption characteristics and energy policies. Through **multivariate regression analysis** and **case studies** we find that socio-demographic and regional characteristics affect attitudes towards energy security. Specifically, we find a strong relationship between level of reliance on oil imports and level of concern for a variety of energy security characteristics including availability, affordability and equity. Our results reaffirm the importance of **gender and age** in shaping perceptions of security, but also extend existing literature by elucidating the impacts of country energy portfolios and policies in shaping climate and security perceptions. Level of development, reliance on oil, and strong energy efficiency policies all affect individuals' sense of energy security. In sum, we find that energy security is a highly context-dependent condition that is best understood from a nuanced and multi-dimensional perspective.

Energy security is embedded in a **complex system** encompassing factors that constitute the social environment in which individuals are immersed. Everything from education, to access to resources to policy and cultural values of particular places affects **perceptions** and **experiences** of energy security. This article examines the types of **energy security challenges that nations face** and characterizes the policy responses that are often used to address these challenges. Drawing from a **survey of energy consumers** in **Brazil, China, Germany, India, Kazakhstan, Japan, Papua New Guinea, Saudi Arabia, Singapore, and the United States**, we conduct a **cross-national comparison of energy security attitudes** as well as analyze each country's energy resources, consumption characteristics and energy policies. Through **multivariate regression analysis** and **case studies** we find that socio-demographic and regional characteristics affect attitudes towards energy security. Specifically, we find a strong relationship between level of reliance on oil imports and level of concern for a variety of energy security characteristics including availability, affordability and equity. Our results reaffirm the importance of **gender** and **age** in shaping perceptions of security, but also extend existing literature by elucidating the impacts of country energy portfolios and policies in shaping climate and security perceptions. Level of development, reliance on oil, and strong energy efficiency policies all affect individuals' sense of energy security. In sum, we find that energy security is a highly context-dependent condition that is best understood from a nuanced and multi-dimensional perspective.



(Source: Brown and Sovacool, 2011)

Fig. 1. Global distribution of energy reserves.
Source: Brown and Sovacool (2011).

- **Availability**—indicating the importance of secure supply of conventional energy, promotion of trade, minimizing depletion of domestic energy, stable price signals, and affordable energy
- **Welfare**—indicating the importance of equity, preserving land, water, and air quality, climate change, greenhouse gas emissions, and transparency
- **Efficiency**—indicating the importance of low energy intensity, small scale energy, R&D, trade, transparency, equity, and education
- **Affordability**—indicating the importance of affordable energy prices, small-scale energy, equity, and R&D
- **Environment**—indicating the importance of preserving land, water, and air quality, stabilizing the climate and reducing greenhouse gas emissions
- **Transparency**—indicating the importance of equity, transparency, and education
- **Climate**—indicating the importance of stabilizing the climate and reducing greenhouse gas emissions (i.e., both climate change mitigation and adaptation)
- **Equity**—indicating the importance of preserving land and water quality, transparency, and equity.

Table 4

Highest and lowest rated dimensions of energy security.

Country	Highest rated	Second highest rated	Third highest rated	Fourth highest rated
High oil import dependence				
Singapore	Water availability	Air pollution	Energy R&D	Security of supply
Japan	Air pollution	Energy R&D	Land degradation	Security of supply
Germany	Energy R&D	Climate change mitigation	Energy intensity	Land degradation
Moderate oil import dependence				
China	Security of supply	Land degradation	Air pollution	Water availability
US	Water availability	Energy R&D	Air pollution	Land degradation
India	Water availability	Security of supply	Energy R&D	Land degradation
Self-sufficient (little to no dependence)				
Kazakhstan	Water availability	Land degradation	Air pollution	Security of supply
Saudi Arabia	Water availability	Air pollution	Security of supply	Energy R&D
Papua New Guinea	Water availability	Land degradation	Affordability	Equitable distribution
Brazil	Energy R&D	Land degradation	Water	Climate change mitigation

Table 5
Multivariate regression analysis of 8 scales.

Variables	Availability Scale	Welfare Scale	Efficiency Scale	Affordability Scale	Environment Scale	Transparency Scale	Climate Scale	Equity Scale	Energy Security Scale
R ²	0.15 ^{***}	0.11 ^{****}	0.12 ^{***}	0.11 ^{***}	0.08 ^{***}	0.13 ^{***}	0.06 ^{***}	0.13 ^{***}	0.13 ^{***}
Gender									
Female	+0.09 ^{***}	+0.11 ^{***}	+0.08 ^{***}	+0.11 ^{***}	+0.12 ^{***}	+0.10 ^{***}	+0.25 ^{***}	+0.10 ^{***}	0.10 ^{***}
Age									
18–25 (baseline)									
26–35									
36–45									
46–55	+0.09 ^{**}								
55+	+0.11 ^{**}	+0.11 ^{**}	+0.14 ^{***}	+0.15 ^{***}		+0.16 ^{***}		+0.14 ^{***}	+0.18 ^{***}
Education									
Other (baseline)									
Secondary								–0.08 [*]	
Undergraduate					–0.08 [*]			–0.09 ^{**}	
Post Graduate	–0.14 ^{***}		–0.08 ^{**}	–0.11 ^{**}	–0.12 ^{**}	–0.15 ^{***}		–0.17 ^{***}	–0.11 ^{***}
Occupation									
Private Sector (baseline)									
Government						+0.08 [*]			
Non-Profit	–0.10 [*]								
University									
Other									
Residence									
US (baseline)									
Singapore		–0.27 ^{***}	–0.29 ^{***}	–0.15 [*]	–0.27 ^{***}	–0.28 ^{***}	–0.25 ^{**}	–0.30 ^{***}	–0.22 ^{***}
Japan		–0.39 ^{***}	–0.27 ^{***}	–0.17 ^{***}	–0.35 ^{***}	–0.47 ^{***}	–0.32 ^{***}	–0.46 ^{***}	–0.20 ^{***}
Germany		–0.21 ^{***}			–0.20 ^{***}	–0.21 ^{***}		–0.23 ^{***}	
India	+0.50 ^{***}	+0.08 ^{**}	+0.16 ^{***}	+0.21 ^{***}	+0.09 ^{**}	+0.11 ^{**}		–0.10 ^{**}	+0.23 ^{***}
China	+0.21 ^{***}		–0.20 ^{***}	–0.10 ^{**}		–0.30 ^{***}		–0.16 ^{***}	
Kazakhstan	+0.52 ^{***}			+0.17 ^{**}					+0.19 ^{***}
Saudi Arabia	+0.35 ^{***}		+0.13 ^{**}	+0.24 ^{***}					+0.14 ^{***}
Papua New Guinea	+0.41 ^{***}		+0.18 ^{***}	+0.30 ^{***}		+0.26 ^{***}		+0.17 ^{***}	+0.19 ^{***}
Brazil	+0.58 ^{***}	+0.22 ^{***}	+0.31 ^{***}	+0.44 ^{***}	+0.20 ^{***}	+0.28 ^{***}	+0.29 ^{***}	+0.22 ^{***}	+0.34 ^{***}
Other							–0.19 [*]		

*** Significant at the 99% confidence interval.

** Significant at the 95% confidence interval

* Significant at the 90% confidence interval

Appendix A

Composite measures incorporated into each scaled variable.

Variables	Availability Scale	Welfare Scale	Efficiency Scale	Affordability Scale	Environment Scale	Transparency Scale	Climate Scale	Equity Scale	Energy Security Scale
Eigen Value	1.54	3.37	2.46	1.51	2.70	1.40	1.14	2.24	5.42
Chronbach's Alpha	0.70	0.85	0.78	0.69	0.85	0.76	0.81	0.81	0.87
Secure Oil	X								X
Trade	X		X						X
Depletion	X								X
Price Signal	X			X					X
Affordable price	X			X					X
Small Scale			X	X					X
Low Energy			X						X
Research & Development			X	X					X
Equity		X	X	X		X		X	X
Transparency			X			X		X	X
Education			X			X		X	X
Land		X			X			X	X
Water		X			X			X	X
Pollution		X			X				X
Climate Change		X			X		X		X
Emissions		X			X		X		X

Factor and correlate analysis were used to determine the composites to be incorporated into each scale.



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Competing policy packages and the complexity of energy security



Benjamin K. Sovacool^{a,b,*}, Harry Saunders^{c,d,1}

^a Vermont Law School, Institute for Energy & the Environment, PO Box 96, 164 Chelsea Street, South Royalton, VT 05068-0444, United States

^b Center for Energy Technology, AU-Herning, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark

^c The Breakthrough Institute, United States

^d Decision Processes Incorporated, 3409 Michael Drive, Newbury Park, CA 91320, United States

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ABSTRACT

To underscore both the diversity and severity of **energy security tradeoffs**, this study examines **five different energy security policy packages**—five distinct strategies aimed at **reducing oil dependence, enhancing energy affordability, expanding access to modern energy services, responding to climate change, and minimizing the water intensity of energy production**. It identifies both compelling **synergies and conflicts** between each of the five strategies. The central value of the study is that it turns on its head the widely accepted notion of a “portfolio approach” or “all of the above” strategy to energy policy-making. To make this case, the article begins by elucidating the **complexity and multidimensionality** of energy security as a concept. It then introduces our five energy security policy packages to illustrate how some energy security objectives **complement** each other whereas others **counteract** each other. It concludes by noting that energy security is not an absolute state, and that achieving it only “works” by **prioritizing some dimensions, or policy goals and packages**, more than others.

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A B S T R A C T

To underscore both the diversity and severity of energy security tradeoffs, this study examines five different energy security policy packages—five distinct strategies aimed at reducing oil dependence, enhancing energy affordability, expanding access to modern energy services, responding to climate change, and minimizing the water intensity of energy production. It identifies both compelling synergies and conflicts between each of the five strategies. The central value of the study is that it turns on its head the widely accepted notion of a “portfolio approach” or “all of the above” strategy to energy policy-making. To make this case, the article begins by elucidating the complexity and multidimensionality of energy security as a concept. It then introduces our five energy security policy packages to illustrate how some energy security objectives complement each other whereas others counteract each other. It concludes by noting that energy security is not an absolute state, and that achieving it only “works” by prioritizing some dimensions, or policy goals and packages, more than others.

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Drexel Kleber, the Director of the Strategic Operations Power Surety Task Force, at the U.S. Department of Defense, argues that energy security is an amalgamation of the “five Ss:”

- **Surety:** The degree of certainty regarding access to energy and fuel sources;
- **Survivability:** The resilience and durability of the existing system in the face of potential damage;
- **Supply:** The physical availability of energy resources;
- **Sufficiency:** The adequacy of supply from a variety of sources;
- **Sustainability:** The degree to which supply can be prolonged and environmental consequences associated with use can be mitigated. [18]

Table 1

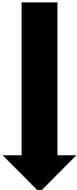
Conceptualizing energy security.

Criteria	Underlying values	Explanation
<i>Availability</i>	Availability and access	The bedrock of providing energy security entails prolonged access to sufficient supplies of energy fuels and services.
<i>Affordability</i>	Affordability and equity	Energy security is further accomplished by energy systems that exhibit stable and affordable cost profiles, both for current and future generations.
<i>Resilience</i>	Malleability and safety	Energy security is improved by energy systems that are both safe and technologically resilient.
<i>Sustainability</i>	Indirect consequences and externalities	Energy security is further enhanced when energy systems integrate effectively with environmental, social and economic objectives, both for current and future generations.
<i>Governance</i>	Quality of governance, transparency, and accountability	Energy security is attained when the system is managed by accountable personnel working in transparent institutions, which provide high quality information about energy production and use.

Table 2

Security challenges with specific energy systems and technologies.

Technology		Availability	Affordability
Oil	Pros	Historically in plentiful supply; readily transported	Historical range \$25–30/barrel was cheap
	Cons	Majority of supply in unstable nations; finite source running out.	Current range (\$100) presenting economic hardship
Natural gas	Pros	Historically in plentiful supply; readily transported	Historically, cheap source of peak load fuel
	Cons	Significant supply in unstable nations; finite source running out.	Potentially expensive after low-cost reserves are depleted



Time can influence energy security, given that energy security problems can unfold at different rates. Jansen identified five different time dimensions of energy security challenges:

- near real-time, or less than 1 min;
- the short term, or less than 2 years;
- the medium run, or 2–15 years;
- The long run, or greater than 15 years;
- The very long term, or greater than 50 years. [\[30\]](#)

To pragmatically illustrate this relativity and complexity of energy security, this section of the paper presents **five separate energy security policy packages**, each one intended to achieve a different energy security goal. These five packages are:

- **Oil self-sufficiency**, the priority of this package being lessening a country's dependence on imported fuels;
- **Energy affordability**, the priority here being the provision of energy services at the cheapest price possible;
- **Energy access**, the priority here providing universal access to electricity grids and modern energy services for heating and cooking;
- **Climate change mitigation**, the priority here mitigating greenhouse gas emissions and lowering the carbon footprint of the energy sector; and
- **Water availability**, the priority here promoting systems of energy production that can operate in areas of water stress and scarcity.

[48,49] One study identified five major disruptions in the global oil market in the two decades *after* the famed oil shocks of the 1970s:

- the Gulf War of 1990 and 1991, which removed 4.3 mbd (million barrels per day) of oil production from the market;
- suspension of Iraqi oil exports in 2001, which removed 2.1 mbd;
- a Venezuelan strike in 2003 and 2004, which removed 2.6 mbd;
- the Gulf War of 2003, which removed 2.3 mbd;
- Hurricane Katrina in 2005, which removed 1.5 mbd. [50]

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Viability of hydrogen pathways that enhance energy security: A comparison of China and Denmark

Jingzheng Ren ^{a,b}, Kristian Peter Andreasen ^{a,*}, Benjamin K. Sovacool ^a

^a AU-Herning, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark

^b CESQA (Quality and Environmental Research Centre), University of Padova, Department of Industrial Engineering, Via Marzolo 9, 35131 Padova, Italy

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ABSTRACT

Abstract: When designed and built properly, **hydrogen energy systems** can enhance **energy security** through **technological diversification** and **minimizing dependence on foreign imports of energy fuels**. However, hydrogen can be produced from different feedstocks according to separate pathways, and these different pathways create particular consequences on a nation's overall energy security. The objective of this study is to investigate the superiorities and inferiorities of hydrogen pathways from the perspective of **China and Denmark**, and to determine which pathways best contribute to national energy security objectives. The results are useful for stakeholders and energy analysts so that they can correctly plan and research the most socially optimal portfolio of hydrogen technologies.

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Abstract: When designed and built properly, hydrogen energy systems can enhance energy security through technological diversification and minimizing dependence on foreign imports of energy fuels. However, hydrogen can be produced from different feedstocks according to separate pathways, and these different pathways create particular consequences on a nation's overall energy security. The objective of this study is to investigate the superiorities and inferiorities of hydrogen pathways from the perspective of China and Denmark, and to determine which pathways best contribute to national energy security objectives. The results are useful for stakeholders and energy analysts so that they can correctly plan and research the most socially optimal portfolio of hydrogen technologies.

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- (1) **Availability** (A_1), which covers *geological* existence. It is used to measure the reserves of resources and energies for hydrogen production.
- (2) **Accessibility** (A_2), which covers *geopolitical* elements. This criterion is to measure governmental support.
- (3) **Affordability** (A_3), which covers *economical* performances. It is to measure the cost of hydrogen production.
- (4) **Acceptability** (A_4), which covers *environmental* issues. It aims at measuring the environmental impacts of hydrogen production pathways.
- (5) **Applicability** (A_5), which covers *technological* concerns. It reflects the maturity of the technologies for hydrogen production and utilization.



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Quantifying, measuring, and strategizing energy security: Determining the most meaningful dimensions and metrics



Jingzheng Ren ^{a, b, *}, Benjamin K. Sovacool ^{b, c}

^a CESQA (Quality and Environmental Research Centre), Department of Industrial Engineering, University of Padova, Via Marzolo 9, 35131 Padova, Italy

^b Center for Energy Technologies, AU-Herning, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark

^c Vermont Law School, Institute for Energy & the Environment, PO Box 96, 164 Chelsea Street, South Royalton, VT 05068-0444, United States

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ABSTRACT

Various metrics exist for energy security assessment along with a diffuse array of different strategies for improving national performance. These independent and interacted metrics overlap, however, and are rarely considered systematically. The objective of this study is to translate often subjective concepts of energy security into more objective criteria, to investigate the cause-effect relationships among these different metrics, and to provide some recommendations for the stakeholders to draft efficacious measures for enhancing energy security. To accomplish this feat, the study utilizes a DEMATEL (Fuzzy Decision-making Trial and Evaluation Laboratory) methodology to analyze collected data, reveal cause-effect relationships, and prioritize energy security strategies. To apply our theoretical results in practice, we include a brief case study of China. We conclude that the availability and affordability dimensions of energy security are most impactful to a nation's overall energy security, and that the promotion of renewable energy and diversification are compelling national energy security strategies, both for China and other countries.

A B S T R A C T

Various metrics exist for energy security assessment along with a diffuse array of different strategies for improving national performance. These independent and interacted metrics overlap, however, and are rarely considered systematically. The objective of this study is to translate often subjective concepts of energy security into more objective criteria, to investigate the cause-effect relationships among these different metrics, and to provide some recommendations for the stakeholders to draft efficacious measures for enhancing energy security. To accomplish this feat, the study utilizes a DEMATEL (Fuzzy Decision-making Trial and Evaluation Laboratory) methodology to analyze collected data, reveal cause-effect relationships, and prioritize energy security strategies. To apply our theoretical results in practice, we include a brief case study of China. We conclude that the availability and affordability dimensions of energy security are most impactful to a nation's overall energy security, and that the promotion of renewable energy and diversification are compelling national energy security strategies, both for China and other countries.

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Dimensions and metrics of Energy Security:

□ **Availability** (A1)

- ✓ Security of supply (A11) =
$$\frac{\text{total production energy}}{\text{total consumed energy}}$$
- ✓ Self-sufficiency (A12) =
$$\frac{\text{imported energy}}{\text{total consumed energy}}$$
- ✓ Diversification (A13) = diversity index, e.g. Shannon-Wiener

Dimensions and metrics of Energy Security:

□ **Availability** (A1)

- ✓ Renewable energy (A14) =
$$\frac{\text{renewable energy}}{\text{total consumed energy}}$$
- ✓ Technological maturity (A15) = **qualitative**

Dimensions and metrics of Energy Security:

❑ **Affordability** (A2)

- ✓ Price stability (A21) = **deviations of price to global mean value**
- ✓ Dependency (A22) =
$$\frac{\text{total imported energy}}{\text{population}}$$
- ✓ Market liquidity (A23) = **qualitative**
- ✓ Decentralization (A24) =
$$\frac{\text{total energy by distributed/small scale generation}}{\text{total energy production}}$$

2.2.2. **Affordability** (A_2)

We argue that the dimension of affordability consists primarily of factors which influence energy prices for households and industries. We propose that such a dimension can be broken down into six metrics:

- **Price stability** (A_{21}): measures the stability of the energy market, and can reflect the resilience to market risks and the soundness of national energy policies. It can be measured by determining the total absolute derivations of the price in different time to the global mean value.
- **Dependency** (A_{22}): assesses imported energy per capita. It can be measured by the total importuned energy divided by the number of the population.

Dimensions and metrics of Energy Security:

☐ **Affordability** (A2)

- ✓ Electrification (A25) = % of population with reliable access to grid
- ✓ Equity (A26) = % of households depending on wood, straw etc. for cooking & heating

Dimensions and metrics of Energy Security:

□ **Acceptability** (A3)

- ✓ Environment (A31) = *several “micro aspects” “measured individually”*
- ✓ Social satisfaction (A32) = **qualitative**
- ✓ National governance (A33) = **qualitative**
- ✓ International governance (A34) = **qualitative**
- ✓ Transparency (A35) = **qualitative**
- ✓ Investment & employment (A36) = **qualitative**

Dimensions and metrics of Energy Security:

☐ **Accessibility** (A4)

- ✓ Import stability (A41) = qualitative
- ✓ Trade (A42) = qualitative
- ✓ Political stability (A43) = qualitative
- ✓ Military power (A44) = qualitative
- ✓ Safety & reliability (A45) = qualitative

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Energy Research & Social Science

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Original research article

Forty years of energy security trends: A comparative assessment of 22 industrialized countries

Marilyn A. Brown^{a,1}, Yu Wang^{b,*}, Benjamin K. Sovacool^{c,2}, Anthony Louis D'Agostino^{d,3}^a School of Public Policy, Georgia Institute of Technology, DM Smith Building, 685 Cherry Street, Room 312, Atlanta, GA 30332-0345, United States^b School of Public Policy, Georgia Institute of Technology, DM Smith Building, 685 Cherry Street, Room 200, Atlanta, GA 30332-0345, United States^c Center for Energy Technologies, AU-Herning, Aarhus University, Birk Centerpark 15, DK-7400 Herning, Denmark^d School of International and Public Affairs, Columbia University, 420 West 118th Street, New York, NY 10027, United States

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ABSTRACT

This article correlates **energy policy** and practice with the multidimensional concept of **energy security** and empirical performance over **forty years**. Based on an analysis of **22 countries** in the Organization for Economic Cooperation and Development **between 1970 and 2010**, it concludes that many industrialized countries have made limited progress toward the goal of achieving secure, reliable and affordable supplies of energy while also transitioning to a low-carbon energy system. However, some national best practices exist, which are identified by examining the relative performance of four countries: the **United Kingdom** and **Belgium** (both with noteworthy improvements), and **Sweden** and **France** (both with limited improvements). The article concludes by offering implications for energy policy more broadly and by providing empirical evidence that our four dimensions (**availability**, **affordability**, **energy efficiency**, and **environmental stewardship**) envelop the key strategic components of energy security.

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A B S T R A C T

This article correlates energy policy and practice with the multidimensional concept of energy security and empirical performance over forty years. Based on an analysis of 22 countries in the Organization for Economic Cooperation and Development between 1970 and 2010, it concludes that many industrialized countries have made limited progress toward the goal of achieving secure, reliable and affordable supplies of energy while also transitioning to a low-carbon energy system. However, some national best practices exist, which are identified by examining the relative performance of four countries: the United Kingdom and Belgium (both with noteworthy improvements), and Sweden and France (both with limited improvements). The article concludes by offering implications for energy policy more broadly and by providing empirical evidence that our four dimensions (availability, affordability, energy efficiency, and environmental stewardship) envelop the key strategic components of energy security.

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For this study, we thus define energy security as “equitably providing available, affordable, reliable, efficient, environmentally benign, proactively governed and socially acceptable energy services to end-users.” This conception of energy security comes from a literature review of energy security offered in Sovacool and Brown [28] as well as research interviews with energy experts and surveys of energy end-users [29–33]. This consequent multidimensional

In some of our previous work, we have argued that energy security consists of four interconnected criteria or dimensions: availability, affordability, efficiency, and environmental stewardship [28,31,34,35]. **Availability** refers to diversifying the fuels used to provide energy services as well as the location of facilities using those fuels, promoting energy systems that can recover quickly from attack or disruption, and minimizing dependence on foreign suppliers. **Affordability** refers to providing energy services that are affordable for consumers and minimizing price volatility. **Efficiency** involves improving the performance of energy equipment and altering consumer behavior in order to reduce energy price exposure and mitigate energy import dependency. **Stewardship** consists of protecting the natural environment, communities, and future generations. Based on an assessment of 91 peer-reviewed academic articles these dimensions are listed above in their order of frequency as shown in [Table 1](#).

Table 1

Defining and measuring energy security.

Dimension	Explanation	Percent of articles
<i>Availability</i>	Diversifying the fuels used to provide energy services as well as the location of facilities using those fuels, promoting energy systems that can recover quickly from attack or disruption, and minimizing dependence on foreign suppliers	82%
<i>Affordability</i>	Providing energy services that are affordable for consumers and minimizing price volatility	51%
<i>Energy and economic efficiency</i>	Improving the performance of energy equipment and altering consumer attitudes to reduce energy price exposure and mitigate energy import dependency	34%
<i>Environmental stewardship</i>	Protecting the natural environment and future generations	26%

Table 2
Energy security performance index for 22 OECD countries, 2010.^a

Country	Availability			Affordability		Energy and economic efficiency			Environmental stewardship	
	Oil import dependence (%)	Petroleum transport fuels (%) ^b	Natural gas import dependence (%)	Real electricity retail prices (US¢/kWh)	Real gasoline prices (\$/L) ^c	On-road fuel intensity (gpm) ^d	Energy per GDP intensity (tBtu/2005US\$GDP)*	Electricity use (kWh/capita)	SO ₂ emissions (million tons) ^e	CO ₂ emissions (million tons)
Australia	21.2%	95.8%	0.0%	12.5	1.27	0.038	7.7	10,386	2.4	424
Austria	82.7%	88.8%	74.8%	20.1	1.63	0.032	5.2	7728	0.0	69
Belgium	98.1%	94.4%	99.3%	16.5	1.87	0.034	7.9	8141	0.1	136
Canada	0.0%	93.2%	0.0%	7.6	1.21	0.043	10.5	15,841	1.4	547
Denmark	0.0%	98.6%	0.0%	39.6	2	0.033	4.6	6083	0.0	46
Finland	93.3%	95.4%	100.0%	17.2	1.94	0.034	7.8	16,185	0.1	55
France	94.4%	91.9%	98.4%	16.9	1.98	0.031	5.6	7300	0.3	389
Germany	92.7%	90.3%	78.0%	26.3	1.9	0.034	5.3	6666	0.4	793
Greece	98.0%	97.9%	100.0%	13.0	2.05	0.034	4.7	5247	0.3	93
Ireland	98.2%	97.5%	93.3%	26.7	1.78	0.034	4.1	5449	0.0	38
Italy	91.0%	92.0%	90.5%	30.5	1.87	0.030	4.9	5050	0.2	417
Japan	96.1%	97.9%	90.4%	20.6	1.6	0.045	5.6	7801	0.8	1180
Netherlands	94.9%	96.6%	0.0%	24.3	2.13	0.033	7.0	6638	0.0	255
New Zealand	46.4%	99.8%	0.0%	16.4	1.47	0.034	7.6	9585	0.1	37
Norway	0.0%	95.3%	0.0%	16.4	2.12	0.034	8.0	25,570	0.0	45
Portugal	97.6%	94.2%	100.0%	22.0	1.85	0.034	5.0	4681	0.1	54
Spain	97.4%	94.7%	99.3%	21.8	1.56	0.032	5.3	5366	0.5	312
Sweden	97.4%	91.8%	105.5%	12.7	1.87	0.036	6.8	15,066	0.0	59
Switzerland	96.2%	94.8%	100.0%	15.4	1.66	0.034	4.4	7728	0.0	42
Turkey	85.4%	98.1%	98.1%	16.5	2.52	0.034	5.3	2190	0.5	269
UK	13.8%	96.3%	40.4%	23.1	1.92	0.032	4.2	5307	0.4	529
United States	48.6%	93.1%	10.8%	11.6	0.76	0.050	7.5	12,564	6.8	5637
Median	93%	95.0%	90%	17.1	1.87	0.034	5.5	7514	0.1	195.6
Mean	70%	94.9%	63%	19.4	1.77	0.036	6.1	8935	0.7	519.4

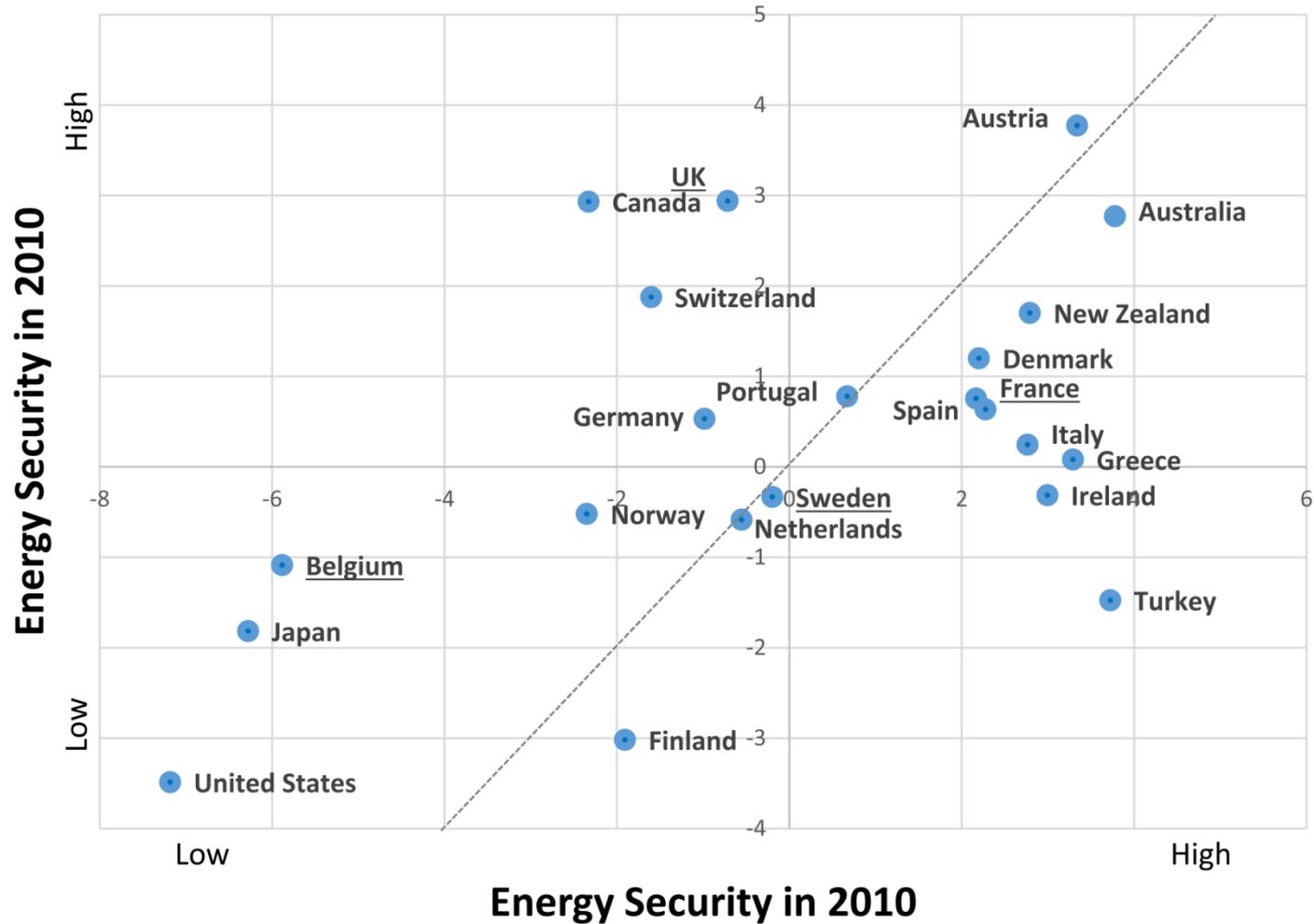
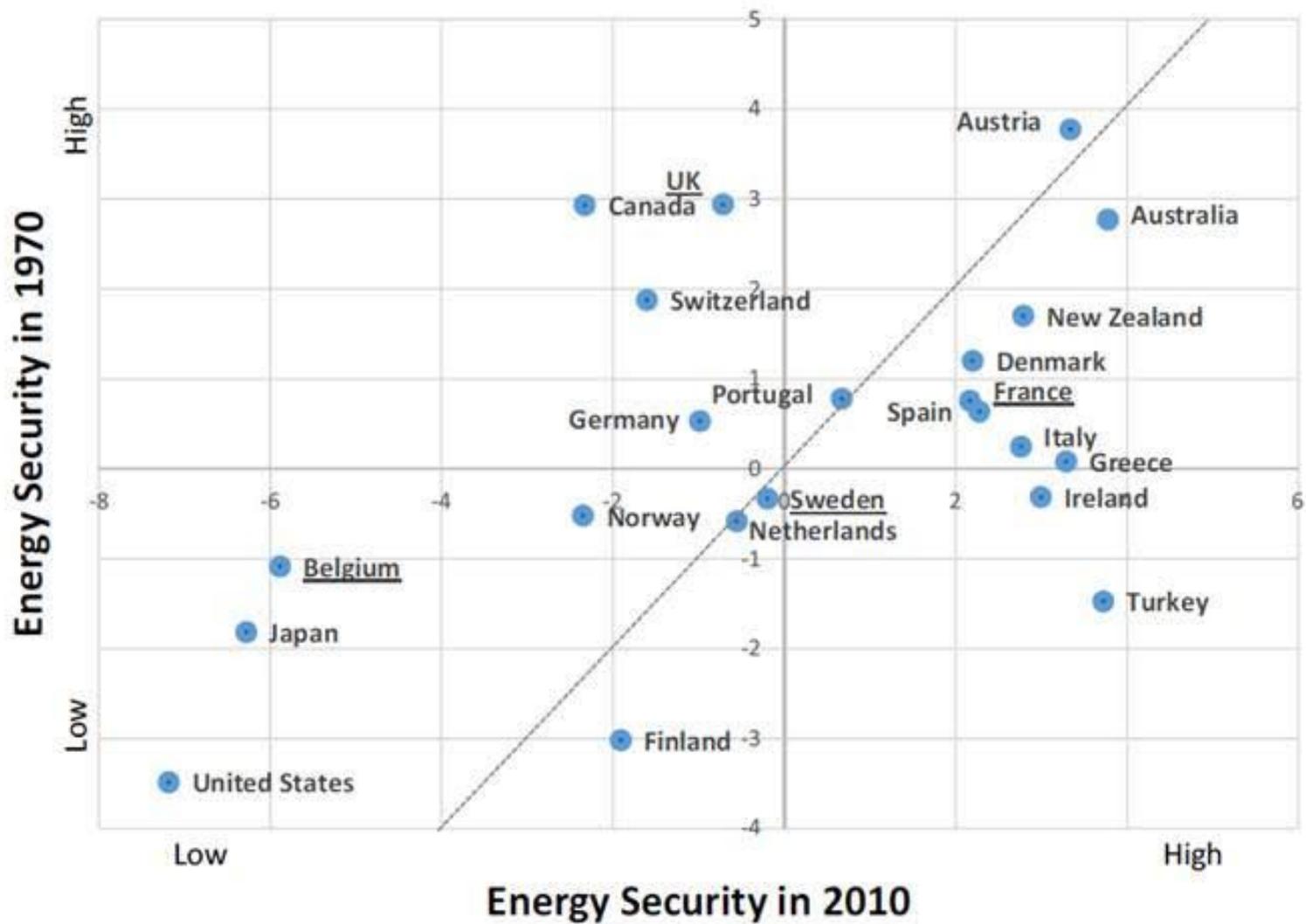


Fig. 1. Energy security “z-scores” in 1970 and 2010. *Note:* case study countries are underlined. Countries above the diagonal line have improved in energy security relative to other OECD countries.



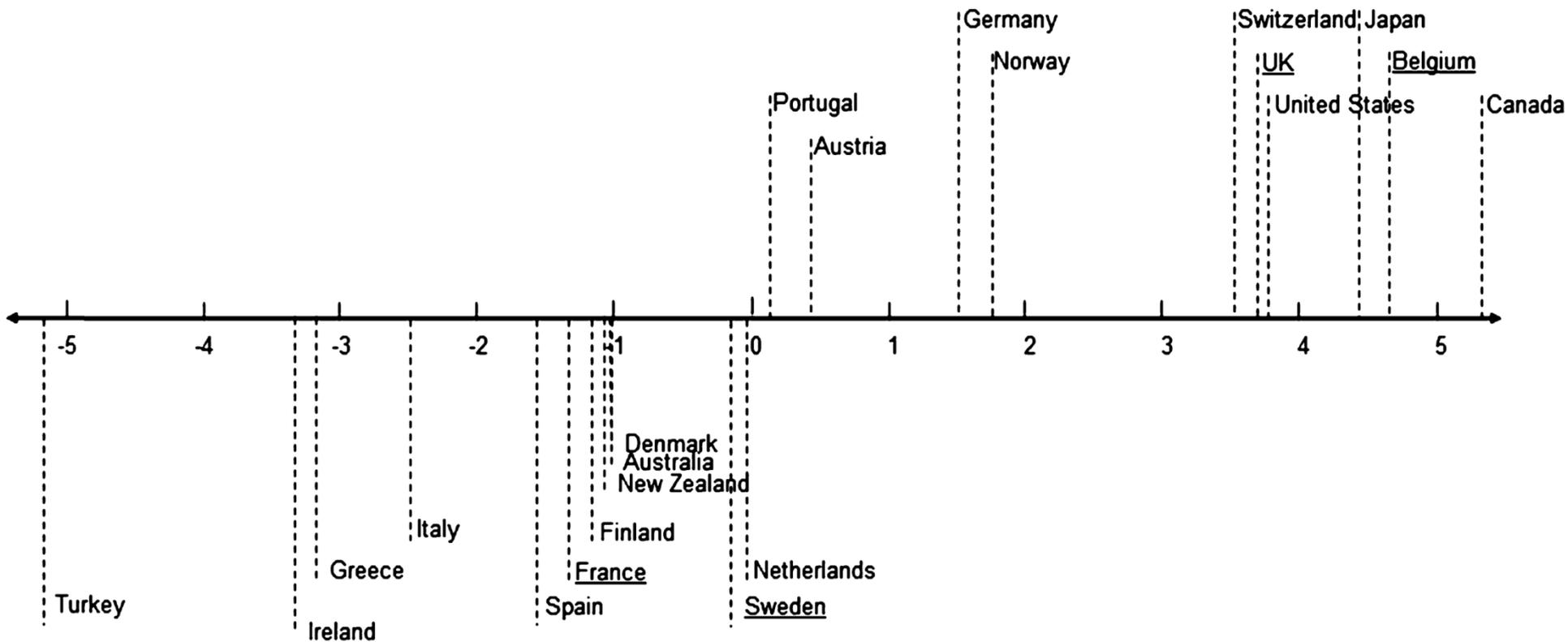


Fig. 2. Most to least improved energy security (based on differences in z-scores: 2010–1970). *Note:* case study countries are underlined.

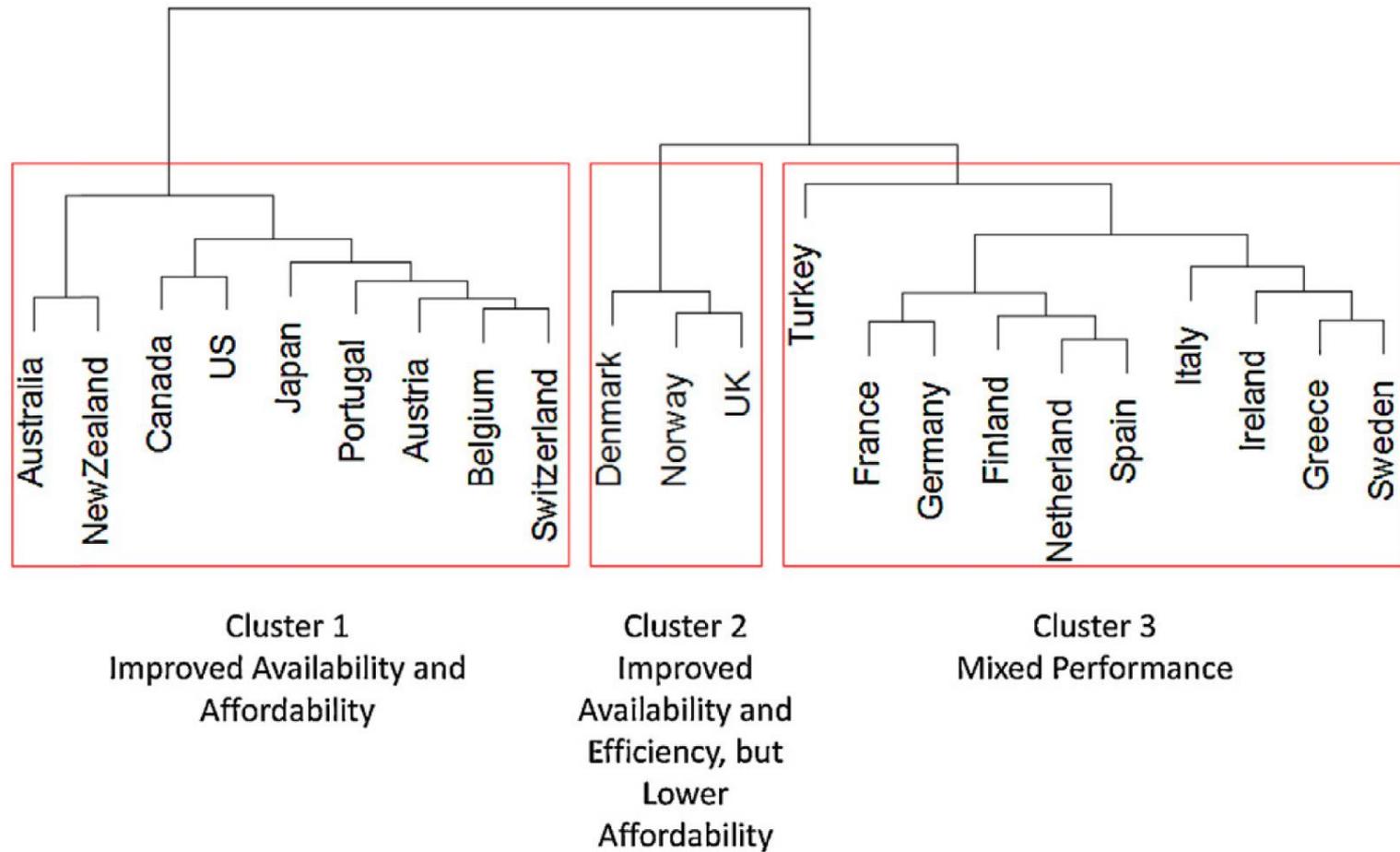


Fig. 3. Clusters of countries with common changes in z-scores for 10 energy security indicators, from 1970 to 2010.

Table 4

Factor loadings and variance explained, based on z-scores of energy security indicators in 1970 and 2010.

	Factor 1 <i>Environmental stewardship</i>	Factor 2 <i>Availability</i>	Factor 3 <i>Energy and economic efficiency</i>	Factor 4 <i>Affordability</i>
<i>Availability</i>				
Oil import dependence	-0.211	0.965	-0.139	
Petroleum transport fuels	-0.264		-0.127	
Natural gas import dependence		0.522	-0.128	0.218
<i>Energy and economic efficiency</i>				
On-road fuel intensity	0.291	-0.528		
Energy per GDP intensity	0.133	-0.220	0.693	-0.389
Electricity use per capita	0.104	-0.171	0.960	-0.166
<i>Affordability</i>				
Electricity retail prices			-0.302	0.658
Gasoline retail prices	-0.257	0.205		0.586
<i>Environmental stewardship</i>				
SO ₂ emissions	0.916	-0.246		-0.259
CO ₂ emissions	0.975	-0.162		-0.131
SS loadings	2.089	1.700	1.560	1.086
Proportion variances	20.9%	17.0%	15.6%	10.9%
Cumulative variances	20.9%	37.9%	53.5%	64.4%