University of Piraeus

Energy Security and the Environment

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2023-03

ENVIRONMENTAL ISSUES, CLIMATE CHANGES, AND ENERGY SECURITY IN DEVELOPING ASIA

Benjamin K. Sovacool

NO. 399

June 2014

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Region served	Asia-Pacific
Membership	67 countries
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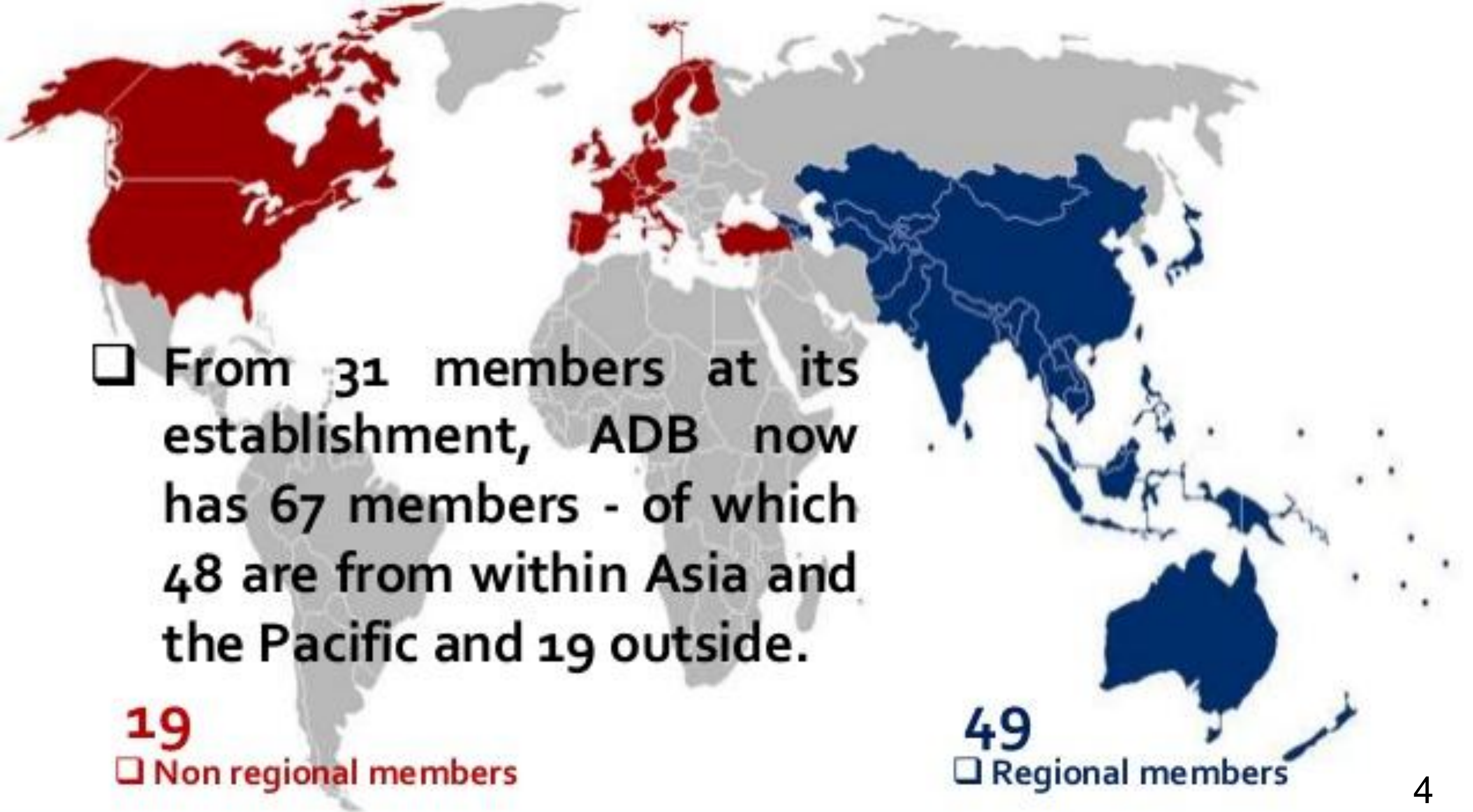

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Environmental Issues, Climate Changes, and Energy Security in Developing Asia

Benjamin K. Sovacool

No. 399 | 2014

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CHINA
Taipei
Taiwan
Hong Kong S.A.R.
Macau S.A.R.
Okino-tori-shima (JAPAN)
Marcus Island (JAPAN)
Midway Islands (U.S.)
Tropic of Cancer
HAWAIIAN ISLANDS (U.S.)
Kauai
Oahu
Honolulu
Maui
Hawaii
MOLOKAI FRACTURE ZONE
Philippine Sea
South China Sea
Luzon
Manila
PHILIPPINES
Northern Mariana Islands (U.S.)
Saipan
Hagåtña
Guam (U.S.)
Wake Island (U.S.)
Johnston Atoll (U.S.)
CLARION FRACTURE ZONE
North Pacific Ocean
Challenger Deep (world's greatest ocean depth, -10924 m)
FEDERATED STATES OF MICRONESIA
MARSHALL ISLANDS
Majuro
Koror
PALAU
Palikir
CAROLINE ISLANDS
Kingman Reef (U.S.)
Palmyra Atoll (U.S.)
CLIPPERTON FRACTURE ZONE
Bandar Seri Begawan
BRUNEI
MALAYSIA
Celebes Sea
Borneo
Manado
Tarawa
KIRIBATI (GILBERT ISLANDS)
Howland Island (U.S.)
Baker Island (U.S.)
Jarvis Island (U.S.)
Kiritimati (Christmas Island) (KIRIBATI)
Equator
Yaren District
NAURU
KIRIBATI
RAWAKI (PHOENIX ISLANDS)
LINE ISLANDS
Java Sea
INDONESIA
Makassar
Surabaya
Dili
EAST TIMOR
PAPUA NEW GUINEA
New Guinea
SOLOMON ISLANDS
Honiara
TUVALU
Funafuti
Tokelau (N.Z.)
KIRIBATI
ÎLES MARQUISES
Port Moresby
Arafura Sea
Timor Sea
Darwin
Ashmore and Cartier Islands (AUSTRALIA)
Coral Sea Islands (AUSTRALIA)
Coral Sea
VANUATU
Port-Vila
Mata-Utu
Wallis and Futuna (FRANCE)
SAMOA
Apia
American Samoa (U.S.)
Pago Pago
Cook Islands (N.Z.)
FIJI
Suva
TONGA
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Noumea
Nuku'alofa
Avarua
Papeete
Tahiti
ARCHIPEL DES TUAMOTU
French Polynesia (FRANCE)
Indian Ocean
Port Hedland
GREAT SANDY DESERT
Mount Isa
Townsville
Cairns
Rockhampton
Gladstone
Alice Springs
AUSTRALIA
SIMPSON DESERT
GREAT VICTORIA DESERT
Lake Eyre
Brisbane
Gold Coast
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Adamstown
Pitcairn Islands (U.K.)
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Kalgoorlie
Perth
Bunbury
Esperance
Broken Hill
Adelaide
Canberra
Newcastle
Sydney
Wollongong
Mount Kosciuszko
Melbourne
Kingston
Norfolk Island (AUSTRALIA)
Lord Howe Island (AUSTRALIA)
KERMADEC ISLANDS (N.Z.)
Tasman Sea
South Pacific Ocean
North Island
Auckland
Hamilton
Hastings
Wellington
NEW ZEALAND
Christchurch
South Island
Dunedin
Invercargill
Stewart Island
CHATHAM ISLANDS (N.Z.)
Tasmania
Hobart
Great Australian Bight
Indian Ocean
Scale: 1:36,000,000 at 30°S
Mercator Projection
500 Kilometers
500 Miles


Asia
Japan
North America
North Pacific
Hawaii
Guam
Palau
Micronesia
Kiribati
South America
equator
Solomon Islands
Nauru
PNG
Wallis Futuna
Tuvalu
Tokelau
Samoa
Vanuatu
Fiji
Niue
Cook Islands
Tahiti
Australia
New Caledonia
Tonga
Easter Is
South Pacific
New Zealand

Four environmental dimensions of energy security—climate change, air pollution, water availability and quality, and land-use change—and the environmental impact of 13 energy systems on each are discussed in this paper. Climate change threatens more land, people, and economies in Asia and small Pacific island states than any other part of the planet. Air pollution takes a substantial toll on national health-care expenditures and economies in general. Of the 18 megacities worldwide with severe levels of total suspended particulate matter emissions, 10 are in Asia. Regarding water availability and quality, hydropower, nuclear power, and thermal power account for 10% to 15% of global water consumption, and the volume of water evaporated from reservoirs exceeds the combined freshwater needs of industry and domestic consumption. In the domain of climate change, rising sea levels could contaminate freshwater aquifers possibly reducing potable water supplies by 45%. Changes in land use for fuelwood collection and biofuel production in Southeast Asia have resulted in deforestation at 5 times the global average and 10 times the average for the rest of Asia. Policymakers must begin to incorporate the cost of these negative consequences into energy prices.

Keywords: environment, water policy, climate change, energy security, Asia-Pacific

Environmental constraints, climate change ~ Energy security

Define sustainable development

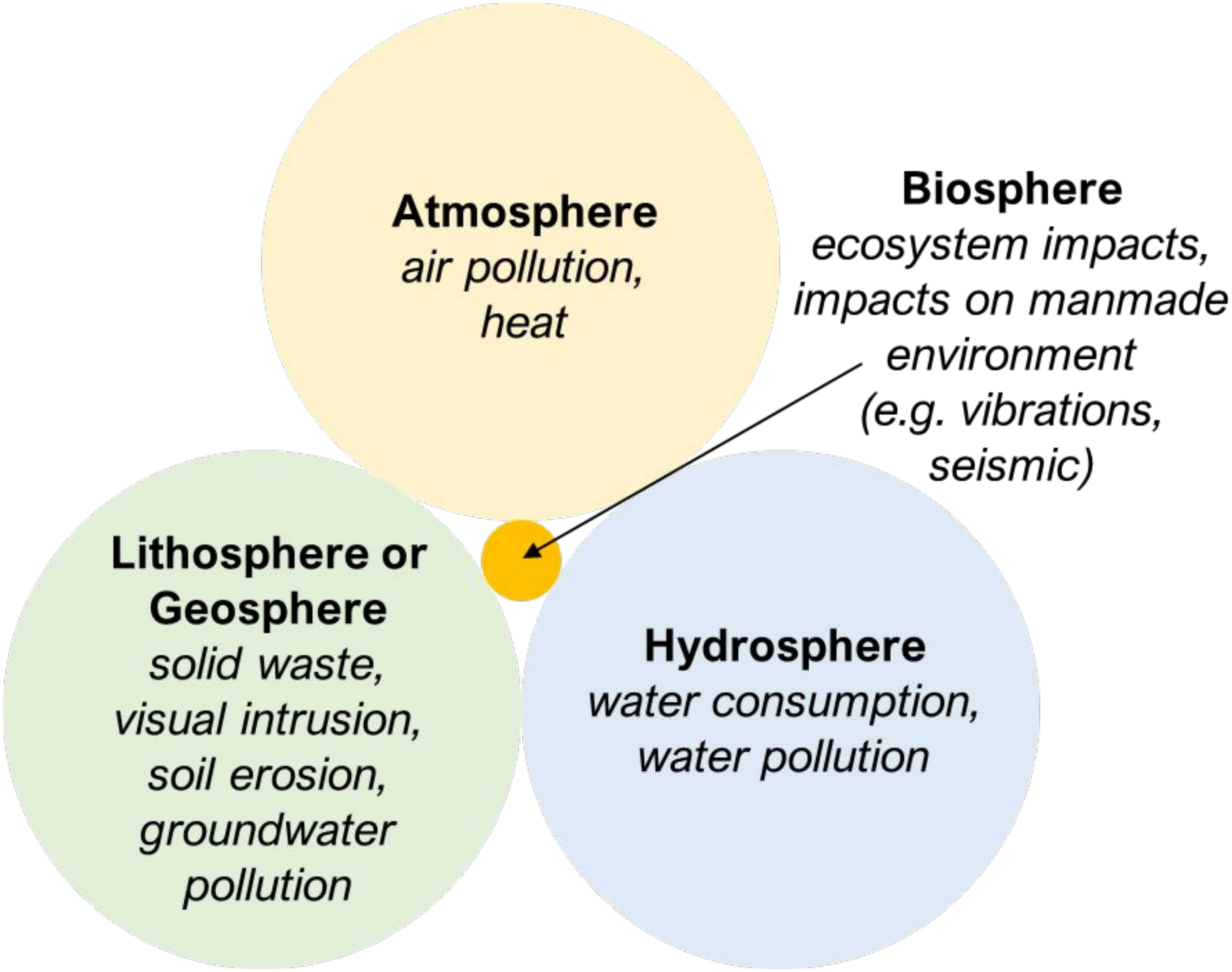
(a) Pressures lead to pollution

Assimilative capacity

(b) Exploitation of natural resources

Rate of (re)growth

Environment ➔ Threat multipliers ➔ Energy security


Atmosphere
air pollution,
heat
Biosphere
ecosystem impacts,
impacts on manmade
environment
(e.g. vibrations,
seismic)
Lithosphere or
Geosphere
solid waste,
visual intrusion,
soil erosion,
groundwater
pollution
Hydrosphere
water consumption,
water pollution


The 4 A's of Energy Security
Availability
Accessibility
Acceptability
Affordability
SafetyCulture

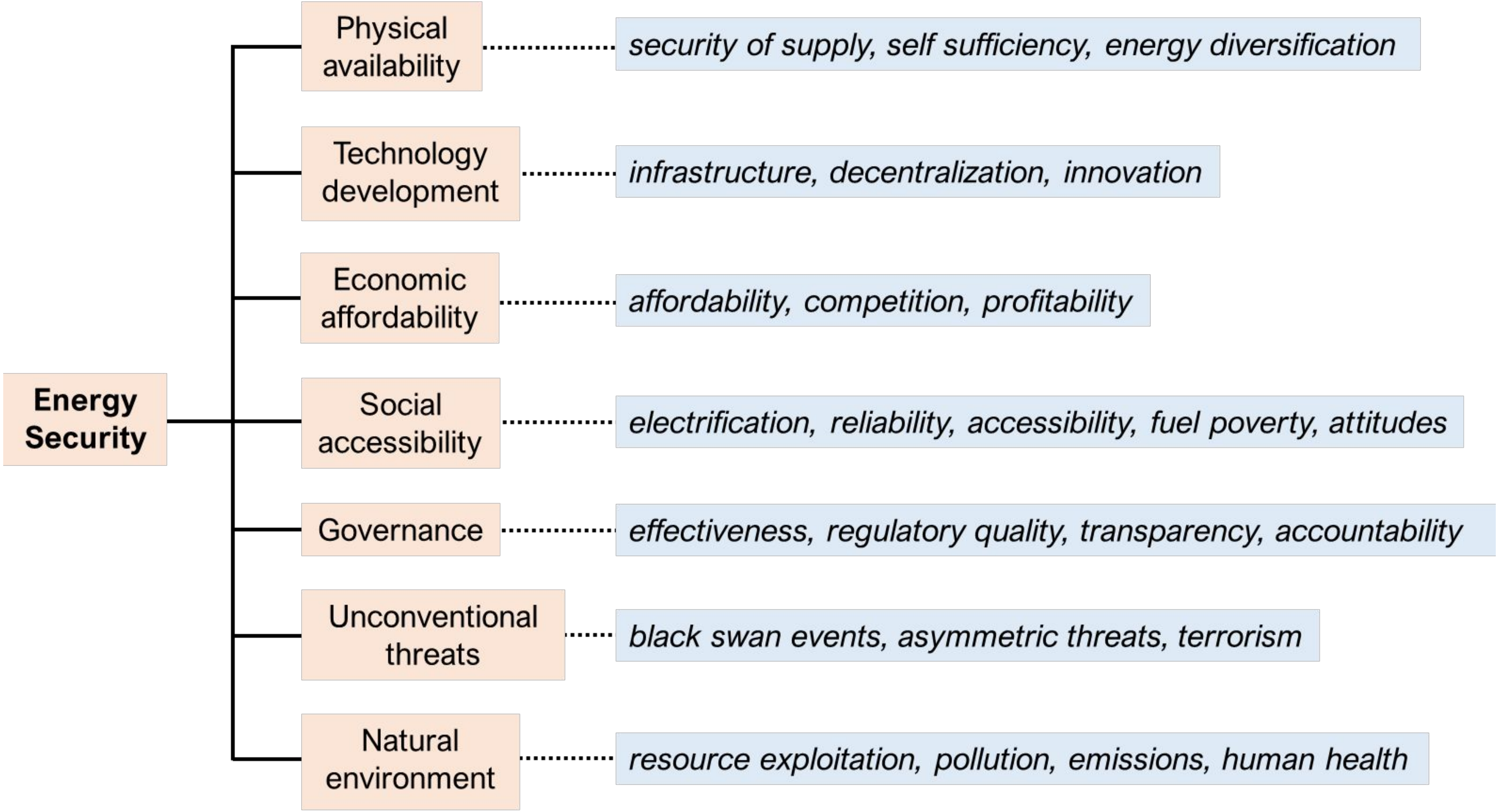
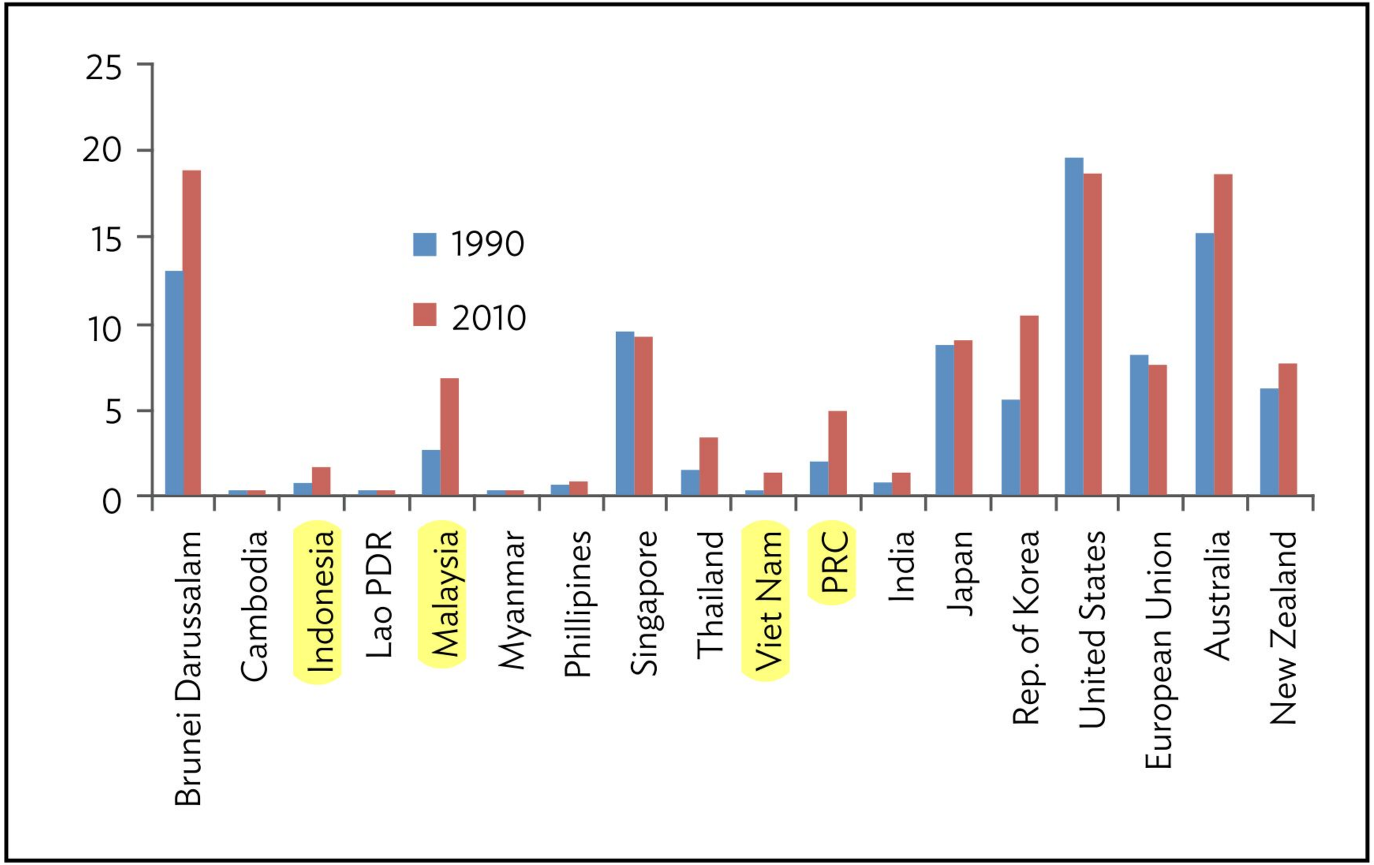

Energy Security
Physical availability
security of supply, self sufficiency, energy diversification
Technology development
infrastructure, decentralization, innovation
Economic affordability
affordability, competition, profitability
Social accessibility
electrification, reliability, accessibility, fuel poverty, attitudes
Governance
effectiveness, regulatory quality, transparency, accountability
Unconventional threats
black swan events, asymmetric threats, terrorism
Natural environment
resource exploitation, pollution, emissions, human health

Table 1: Environmental Dimensions of Energy Security in Asia and the Pacific

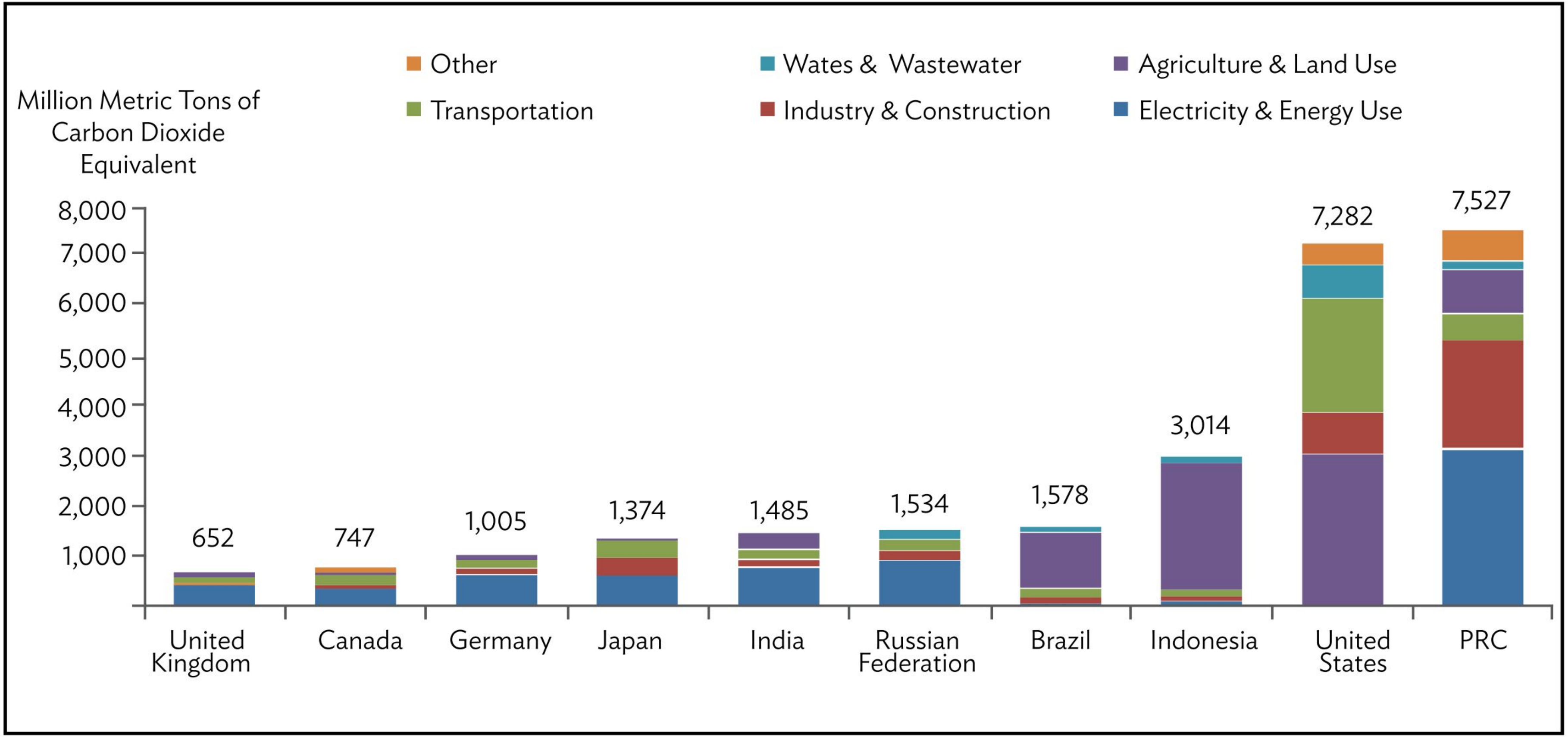
Dimension	Link To Energy Security	Energy Contribution To The Problem
Climate Change	• Climate change is a "threat multiplier" in terms of energy security. • Mass migrations of refugees seeking asylum from ecological disasters could destabilize regions of the world threatening energy as well as national security.	A total of 66.5% of global carbon dioxide emissions come from energy supply and transport.
Air Pollution	• Deterioration of environmental conditions can negatively impact human and ecological health with significant numbers of premature deaths related to indoor and outdoor air pollution and significant expenditures lost in terms of lost productivity and healthcare.	About 80% of global sulfur dioxide emissions, 80% of particulate matter emissions, and 70% of nitrogen oxide emissions come from the energy and transport sectors.
Water Availability and Quality	• Lack of available safe drinking water can destabilize the security of a region. • Because fossil, hydro, and nuclear power plants consume large quantities of freshwater, shrinking supplies of water could threaten the ability to provide electricity and the ability of nations to feed themselves.	In all, 25% of global water supply is lost due to evaporation from reservoirs and another 10%–15% of global freshwater is used in thermoelectric power plants.
Land-Use Change	• Deforestation can cause social dislocation, increase the cost of fuelwood, destroy biodiversity, and conflict with agriculture and the preservation of nature reserves.	At least 15% of land-use change is caused by the direct clearing of forests for fuelwood and the expansion of plantations for energy crops.

Figure 1: Per Capita Energy-Related Carbon Dioxide Emissions, 1990 and 2010 (metric tons)



Lao PDR=Lao People's Democratic Republic, PRC=People's Republic of China.
Source: Sovacool et al. 2011.

Figure 2: Share of Greenhouse Gas Emissions in Top Ten Countries, 2010



PRC=People's Republic of China.
Source: Brown and Sovacool 2011.

One wide-ranging survey of climate impacts in Asia and the Pacific from the United States Agency for International Development predicted the following, among other things:

- accelerated river bank erosion, saltwater intrusion, crop losses, and floods in Bangladesh that will displace at least 8 million people and destroy up to 5 million hectares of crops;
- more frequent and intense droughts in Sri Lanka crippling tea yields and reducing national foreign exchange and lowering incomes for low-wage workers;
- higher sea levels inundating half of the agricultural lands on the Mekong Delta causing food insecurity throughout Cambodia, the Lao PDR, and Viet Nam;
- increased ocean flooding and storm surges inundating 130,000 hectares of farmland in the Philippines affecting the livelihoods of 2 million people;
- intensified floods in Thailand placing more than 5 million people at risk and causing $39 billion to $1.1 trillion in economic damages by 2050.[12]

That study concluded that Asia and the Pacific will have more land threatened, more people damaged, and more economic damage from rising sea levels than any other part of the planet. Already, the region accounted for 85% of deaths and 38% of global economic losses due to natural disasters from 1980 to 2009.[13]

Table 2: Estimated Economic and Social Impact of Disasters in Selected Pacific Island Economies, 1950–2008

	Disasters	*Loses ($ 2008)*	*Average Population Affected (%)*		*Average Impact on Gross Domestic Product (%)*	
Country			***Disaster Years***	***All Years***	***Disaster Years***	***All Years***
American Samoa	6	237,214,770	5.81	0.61	7.76	0.82
Cook Islands	9	47,169,811	5.13	0.63	3.48	0.43
Fiji	43	1,276,747,934	5.39	2.74	3.48	0.78
French Polynesia	6	78,723,404	0.53	0.04	0.31	0.02
Guam (United States)	10	3,294,869,936	1.97	0.28	10.13	1.42
Kiribati	4	0	29.19	1.54	0.00	0.00
Marshall Islands	3	0	6.40	0.22	0.00	0.00
New Caledonia	15	69,623,803	0.14	0.03	0.09	0.02
Micronesia, Federated States of	8	11,915,993	6.20	0.65	0.82	0.09
Niue	6	56,461,688	73.15	7.70	80.88	8.51
Papua New Guinea	58	271,050,690	0.69	0.36	0.14	0.07
Samoa	11	930,837,187	21.15	3.71	16.97	2.98
Solomon Islands	21	39,215,686	2.93	0.98	0.52	0.17
Tokelau	4	4,877,822	39.70	2.79		
Tonga	12	129,344,561	21.32	3.37	5.76	0.91
Tuvalu	5	0	3.19	0.28	0.00	0.00
Vanuatu	36	406,402,255	5.33	2.06	3.78	1.46

Table 3: Water Use (Consumption and Withdrawals) for Selected Power Plants (gallons per kilowatt-hour)

	Withdrawals	Consumption	Withdrawals	Consumption	Total
	(Combustion/Downstream)		(Production/Upstream)		
Nuclear	43	0.4	0	0.11	43.5
Coal (mining)	35	0.3	0.17	0.045	35.5
Coal (slurry)	35	0.3	0	0.05	35.3
Biomass/Waste	35	0.3	0.03	0.03	35.3
Natural gas	13.75	0.1	0	0.01	13.9
Solar thermal	4.5	4.6	0	0	9.1
Hydroelectric	0	0	0	4.5	4.5
Geothermal (steam)	2	1.4	0	0	3.4
Solar photovoltaic	0	0	0	0.3	0.3
Wind	0	0	0	0.2	0.2
Energy efficiency	0	0	0	0	0


CARBON
NUCLEAR
WIND
SOLAR
ENERGY EFFICIENCY
ENERGY EFFICIENCY - “THE FIFTH FUEL”

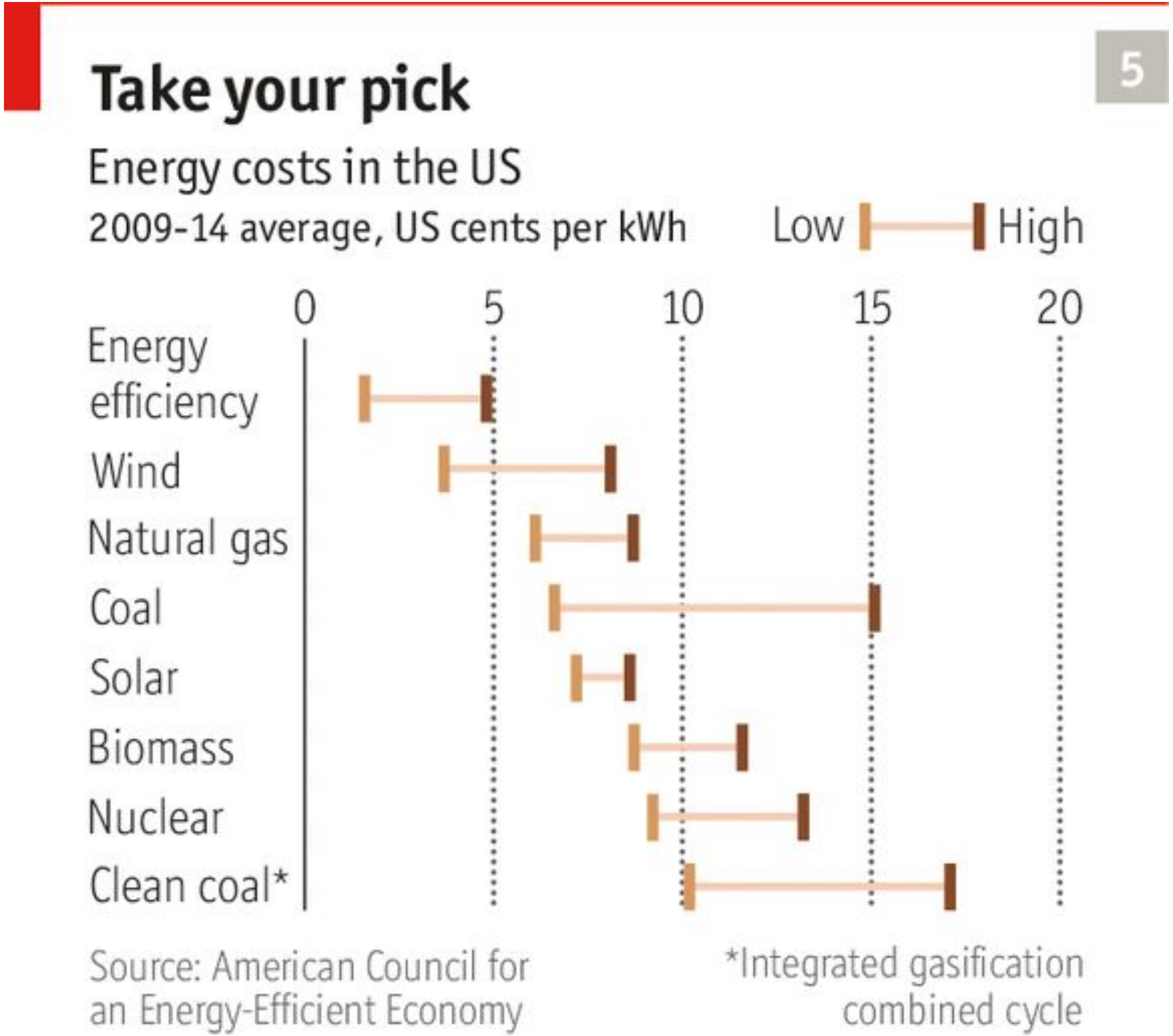
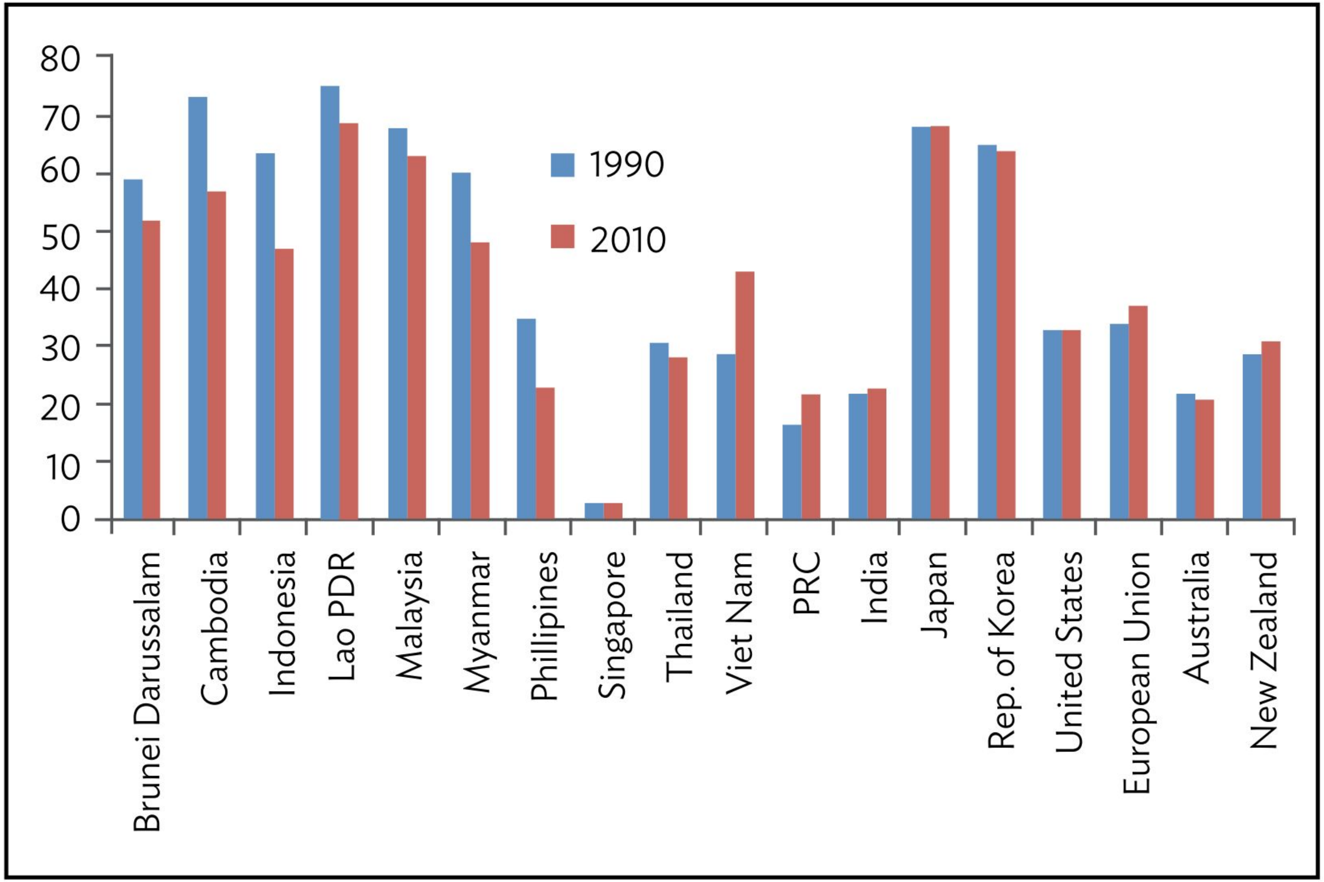

Take your pick
5
Energy costs in the US
2009-14 average, US cents per kWh
Low
High
0
5
10
15
20
Energy efficiency
Wind
Natural gas
Coal
Solar
Biomass
Nuclear
Clean coal*
Source: American Council for an Energy-Efficient Economy
*Integrated gasification combined cycle

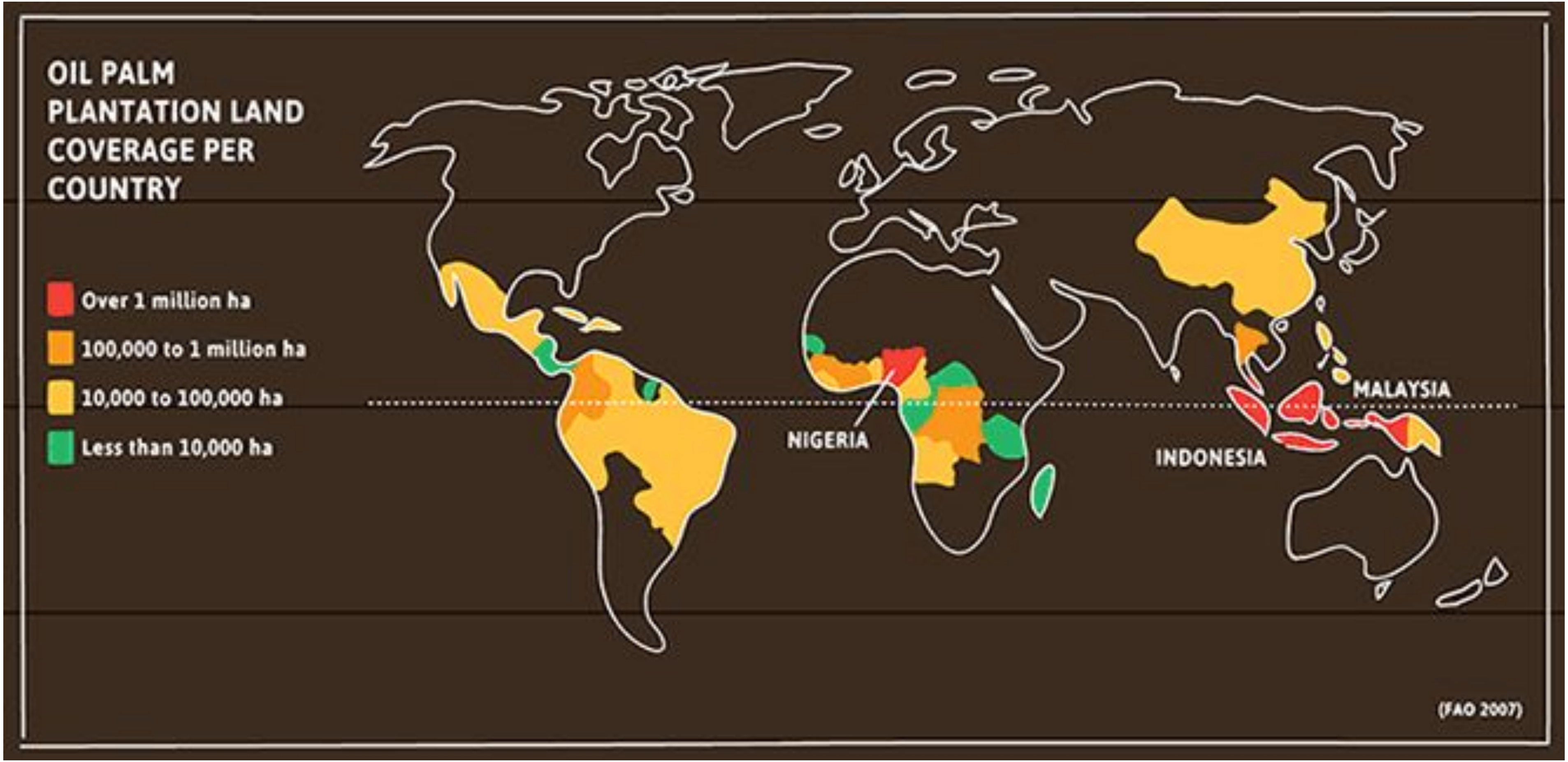
Figure 3: Forest Area as a Percent of Land Area in Selected Countries, 1990 and 2010 (%)

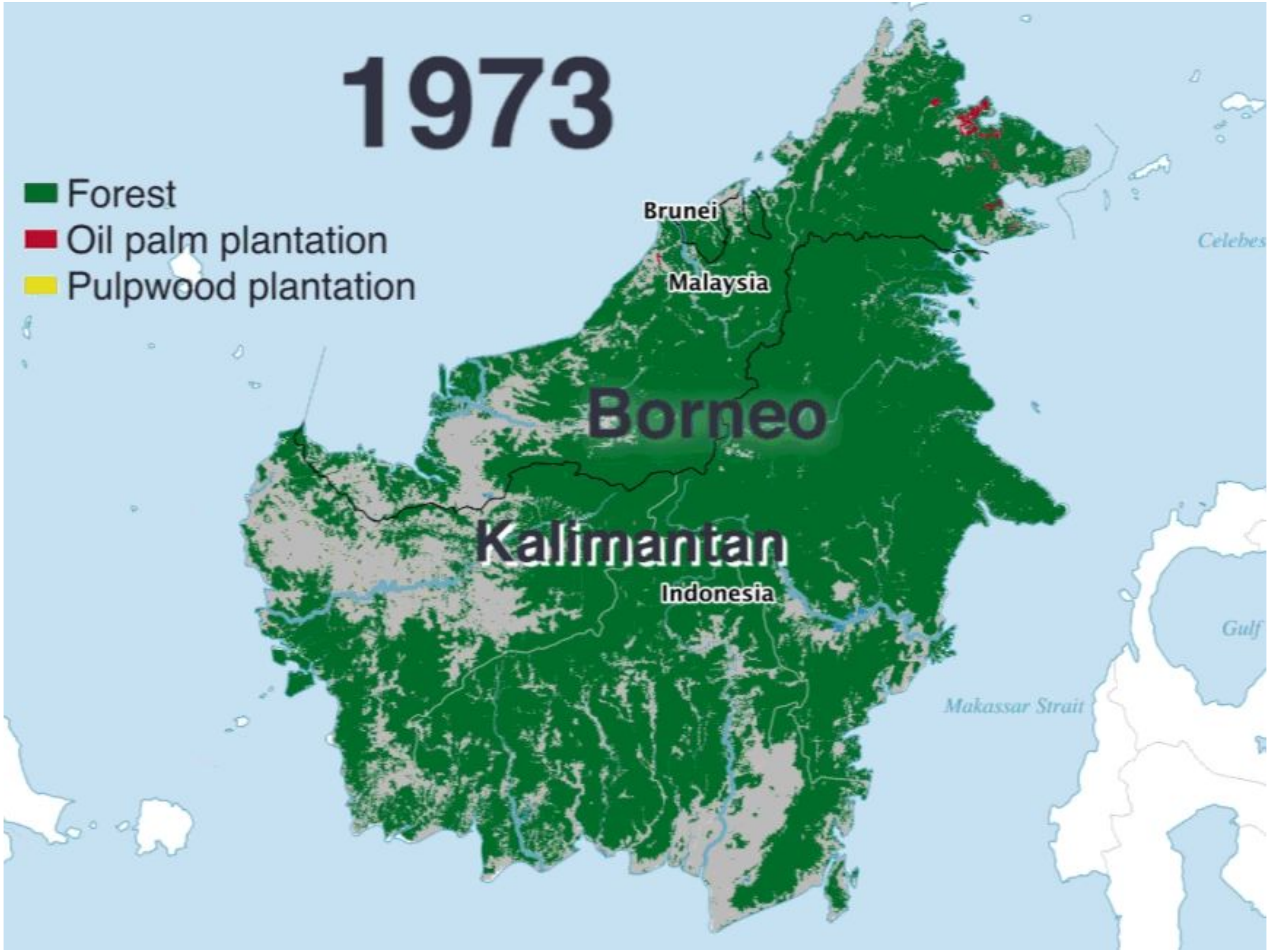


Lao PDR=Lao People's Democratic Republic, PRC = People's Republic of China.

Table 4: Global Leaders in Carbon Dioxide Equivalent Emissions from Deforestation

Country	Share of Emissions from Deforestation (%)
Indonesia	33.7
Brazil	18.0
Malaysia	9.2
Myanmar	5.6
Congo, Democratic Republic of the	4.2
Zambia	3.1
Nigeria	2.6
Peru	2.5
Papua New Guinea	1.9
Total	80.8


OIL PALM
PLANTATION LAND
COVERAGE PER
COUNTRY
Over 1 million ha
100,000 to 1 million ha
10,000 to 100,000 ha
Less than 10,000 ha
NIGERIA
MALAYSIA
INDONESIA
(FAO 2007)


1973
Forest
Oil palm plantation
Pulpwood plantation
Brunei
Malaysia
Borneo
Kalimantan
Indonesia
Celebes
Gulf
Makassar Strait

UNITED NATIONS SUSTAINABLE DEVELOPMENT GOAL

1 NO POVERTY

SUSTAINABLE PALM OIL PRODUCTION FIGHTS POVERTY

COMMUNITIES

Indigenous and forest communities have earned $130,573,000 as a direct result of the RSPO certified sustainable palm oil program

FUTURE

Sustainable farming and processing practices make it possible for current generations to make ends meet while protecting the environment for future generations

CERTIFIED SUSTAINABLE PALM OIL ™ RSPO

CERTIFIED BY RSPO

1,311,001farms are now certified sustainable palm oil producers and are designed to protect ecosystems, workers and local communities.

SUSTAINABLE

103,966,028 acres (42,073,559 ha) of land around the world are under sustainable management as a result of the RSPO programs.

AGROAMERICA

One of AgroAmerica's companies is the 4th palm oil company in the world to be awarded an Identity Preserved RSPO certification and the first in Central America.

AgroAmerica

HTTP://WWW.AGROAMERICA.COM

EU leaders pleased by Malaysia's poverty-reducing oil palm plantations

by **Robin Miller**
on May 13, 2015 in **General**, **News** 0

Four European Parliament members are impressed with how the Malaysian government and its palm oil industry have successfully reduced their country's poverty. As reported in the Borneo Post, Malaysian palm oil cultivation is praised for providing unparalleled upward social mobility to independent farmers. The four European Parliament members visited Malaysia to get a first-hand look at the country's oil palm plantations.

Table 5: Impacts of Energy Systems on Climate Change, Air Pollution, Water Availability and Quality, and Land-Use Change

Energy System	Climate Change	Air Pollution	Water	Land Use
Energy efficiency	Minimal	Minimal	Minimal	Minimal
Nuclear power	Moderate	Minimal	Severe	Severe
Shale gas	Severe	Severe	Severe	Severe
Conventional coal	Severe	Severe	Severe	Severe
Clean coal	Moderate	Severe	Severe	Severe
Oil and gas	Severe	Severe	Severe	Severe
Hydroelectricity	Minimal	Minimal	Severe	Moderate
Wind energy	Minimal	Minimal	Minimal	Moderate
Solar photovoltaics	Minimal	Minimal	Minimal	Moderate
Solar thermal	Minimal	Minimal	Moderate	Moderate
Geothermal	Minimal	Minimal	Moderate	Moderate
Biomass	Minimal	Moderate	Moderate	Moderate
Biofuels	Minimal	Moderate	Severe	Severe

The extraction of coal poses serious problems for communities and ecosystems near mining sites. Coal mining can remove mountaintops by clearing forests and topsoil before using explosives to break up rocks, pushing mine spoils into adjacent streams and valleys. This can cause acid drainage into river systems, destroy ecosystems, blight landscapes, and diminish water quality.[61] One global assessment of the coal mining industry noted that common, "direct" impacts include

> ... fugitive dust from coal handling plants and fly ash storage areas; pollution of local water streams, rivers, and groundwater from effluent discharges and percolation of hazardous materials from the stored fly ash; degradation of land used for storing fly ash; and noise pollution during operation [in addition to] impacts on the health, safety, and well-being of coal miners; accidents and fatalities resulting from coal transportation; significant disruption to human life, especially in the absence of well-functioning resettlement policies; and impacts on the environment such as degradation and destruction of land, water, forests, habitats, and ecosystems.[62]


FLYASH F CLASS

VII. CONCLUSIONS

1. No energy source is free of some type of environmental impact, though energy efficiency practices properly implemented are the most environmentally friendly. While renewable energy sources such as wind and solar have clear environmental benefits compared to conventional sources, they are not free of consequences. Even with the use of renewable resources, every kilowatt-hour of electricity generated, every barrel of oil produced, every ton of uranium mined or cubic foot of natural gas manufactured produces a laundry list of environmental damage that may include radioactive waste and abandoned uranium mines and mills, acid rain and its damage to fisheries and crops, water degradation and excessive consumption, particulate pollution, and cumulative environmental damage to ecosystems and biodiversity through species loss and habitat destruction. In monetary terms, the social and environmental damage from just one type of energy—worldwide electricity generation—amounted to roughly $2.6 trillion in 2010.[91] This means that continuing along the business-as-usual path could result in an increased cost burden to governments as they become saddled with heavy public health-care and environmental costs and the negative effects on economic competitiveness through loss of workforce productivity.[92] Put another way, if the increasing energy demands for the Asian Century scenario are met by the traditional mix of energy supply with current technologies, then the implications for the environment in terms of GHG emissions, green growth, global warming, and prices of fossil fuels would not be sustainable.

2. Policy makers must incorporate the cost of some of these negative environmental consequences of energy production and use into prices. At a bare minimum they should place a price on carbon and preferably other things like sulfur dioxide, nitrogen oxide, particulate matter, and water. A preponderance of evidence suggests that pricing energy more accurately will greatly improve the efficiency of the electricity industry, provide customers with proper price signals, reduce wasteful energy use, and most importantly, improve household incomes since they no longer have to waste as much time and money dealing with debilitating health issues caused by pollution.[93]

3. If policy makers desire to truly promote cleaner forms of energy, feed-in tariffs seem the best method to rapidly accelerate their adoption. One study analyzed renewable portfolio standards, green power programs, public research and development expenditures, system benefit charges, investment tax credits, production tax credits, tendering, and feed-in tariffs, and found that only feed-in tariffs met the criteria for a truly effective policy tool.[94]

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Citizen preferences for possible energy policies at the national and state levels

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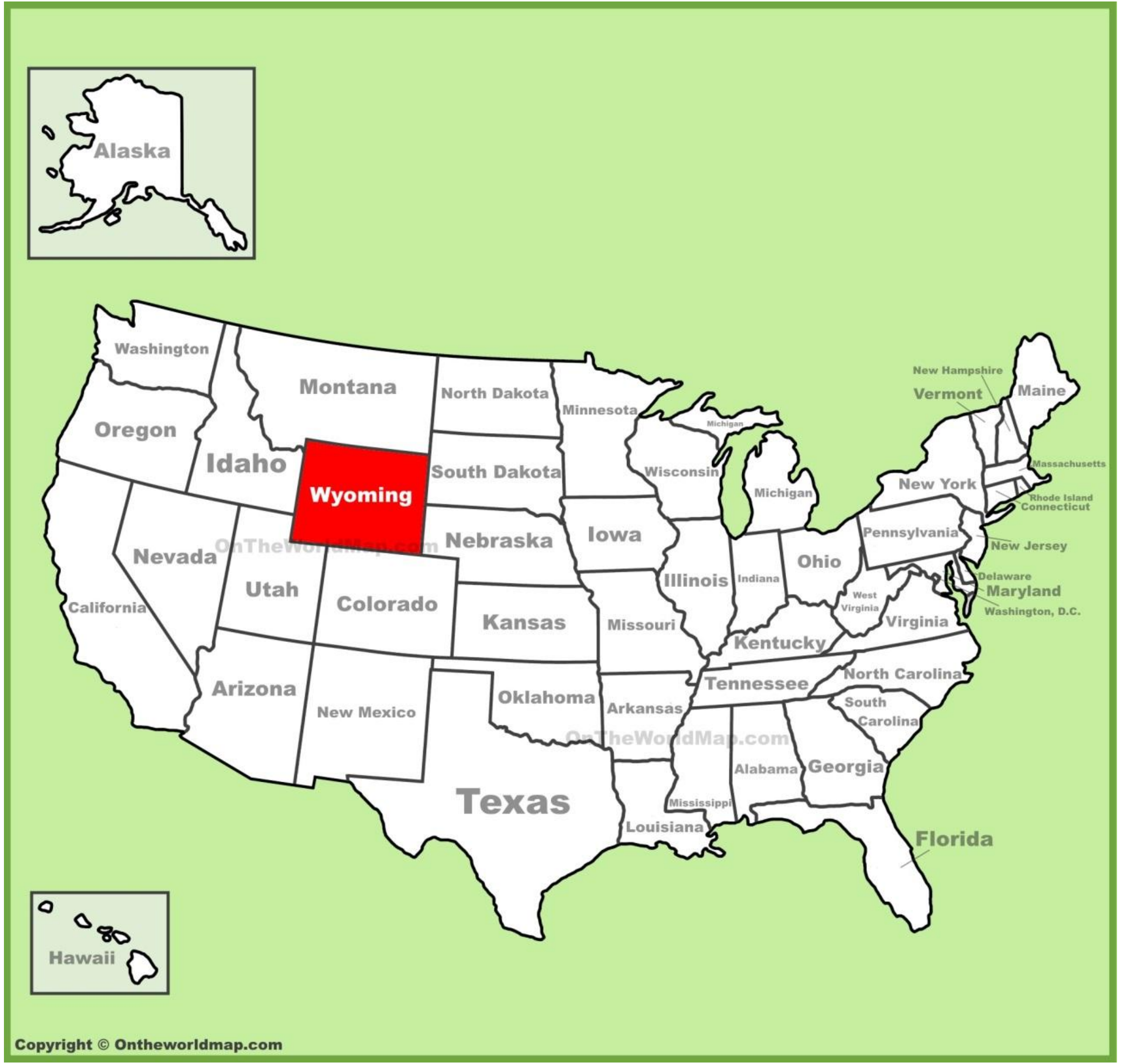
Citizen preferences
Risk aversion
Choice modeling
Discrete choice experiment

ABSTRACT

Without knowledge of citizen preferences, policy makers most often rely on their intuition to infer such preferences or on biased information provided by special interest groups. Using a choice-modeling approach, the study features two large-scale, field-research projects—one done nationally in the US, and another composed of separate data collection efforts across eight states where energy policies have a high profile in public discourse. The results suggest four outcomes of energy policies are most important to citizens at the national level: 1) environmental quality, 2) energy costs, 3) job creation, and 4) greenhouse gas emissions. This pattern of importance for the outcomes of energy policy persists across important demographic groups including those related to political-party affiliation. At the state level, the four preferred outcomes of energy policies seen at the national level also appear—although in a different order of preference in some states. Further analysis of citizens' willingness to change energy policy at the state level suggests that risk aversion characterizes citizens' views about revising energy policy.


Alaska
Washington
Montana
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Oregon
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South Dakota
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Michigan
New Hampshire
Vermont
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New York
Rhode Island
Connecticut
Nevada
Nebraska
Iowa
Pennsylvania
New Jersey
Utah
Colorado
Illinois
Indiana
Ohio
Delaware
Maryland
West Virginia
Washington, D.C.
California
Kansas
Missouri
Virginia
Kentucky
North Carolina
Tennessee
Arizona
New Mexico
Oklahoma
Arkansas
South Carolina
Alabama
Georgia
Texas
Mississippi
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Hawaii
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UNIVERSITY OF WYOMING

A B S T R A C T

Without knowledge of citizen preferences, policy makers most often rely on their intuition to infer such preferences or on biased information provided by special interest groups. Using a choice-modeling approach, the study features two large-scale, field-research projects—one done nationally in the US, and another composed of separate data collection efforts across eight states where energy policies have a high profile in public discourse. The results suggest four outcomes of energy policies are most important to citizens at the national level: 1) environmental quality, 2) energy costs, 3) job creation, and 4) greenhouse gas emissions. This pattern of importance for the outcomes of energy policy persists across important demographic groups including those related to political-party affiliation. At the state level, the four preferred outcomes of energy policies seen at the national level also appear—although in a different order of preference in some states. Further analysis of citizens' willingness to change energy policy at the state level suggests that risk aversion characterizes citizens' views about revising energy policy.

Translating our objectives into research questions results in the following:

RQ1: How will environmental outcomes of energy policy compare in preference to outcomes for energy consumption and for economic development?

RQ2: What would be the pattern of preferences across sub-groups defined by political-party affiliation?

RQ3: How much risk-aversion will citizens manifest in anticipated response to changes in outcomes of energy policies?

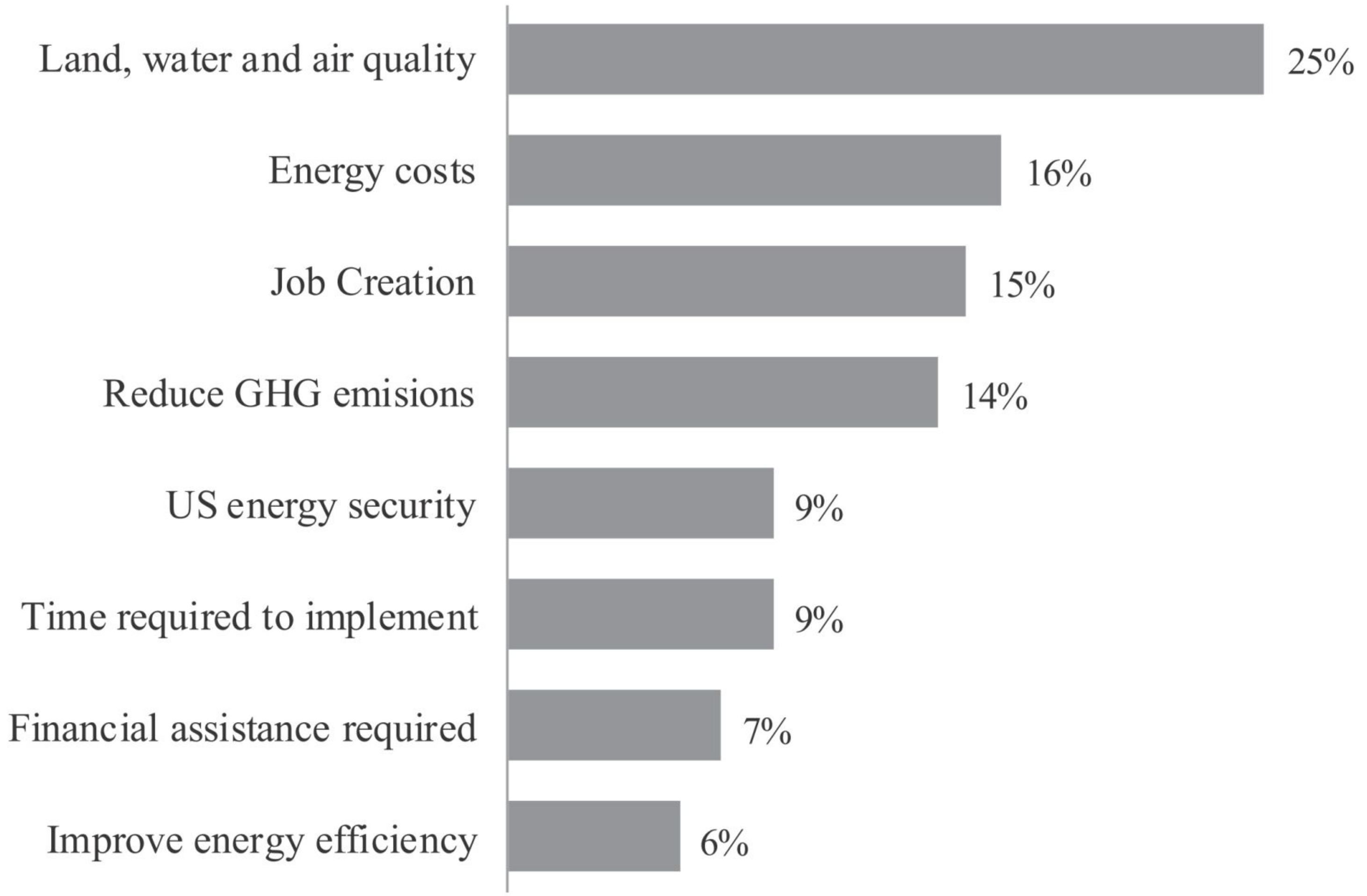


Fig. 1. Relative Importance of the Eight Policy Components of Study 1.

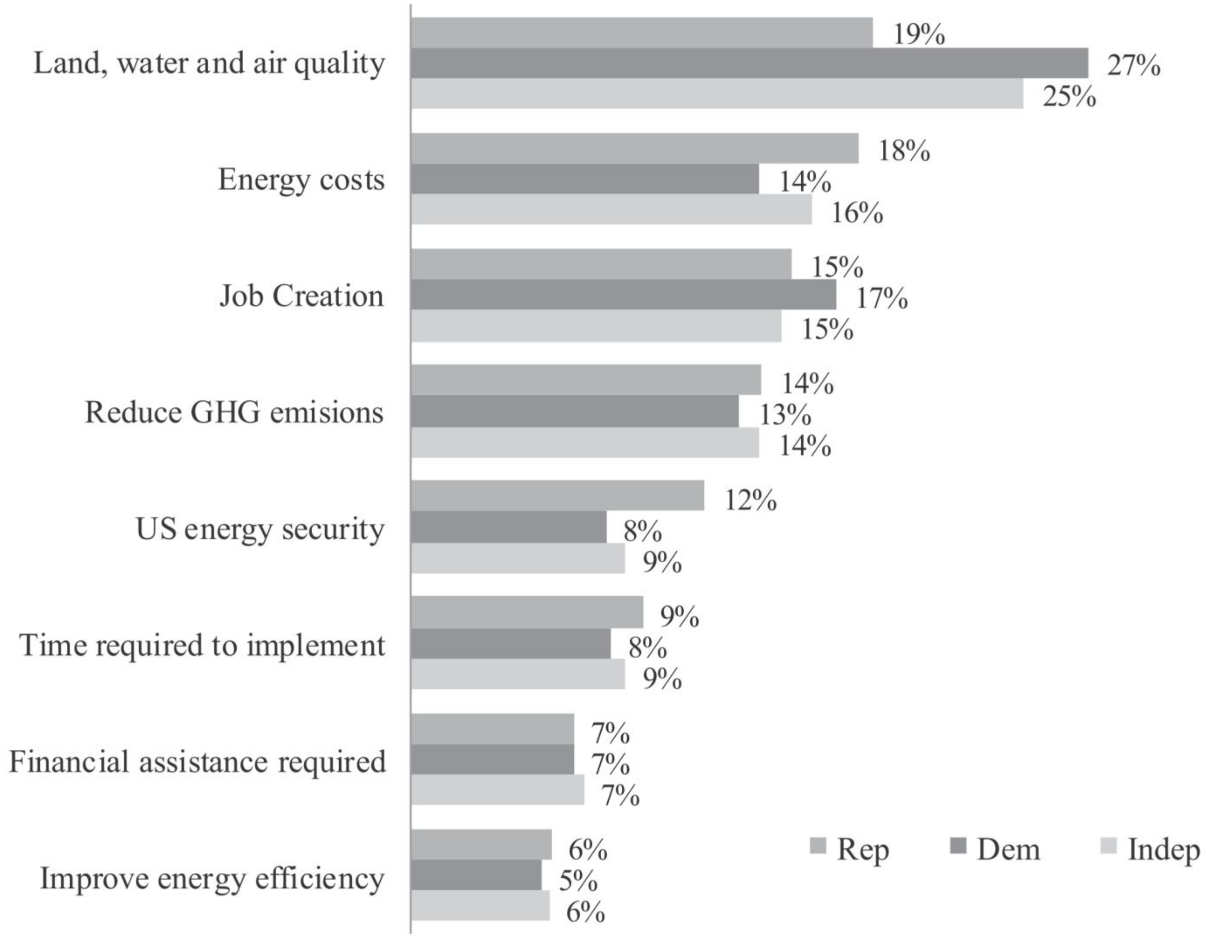


Fig. 2. Relative Importance of the Eight Policy Components of Study 1 by Political Party Affiliation.

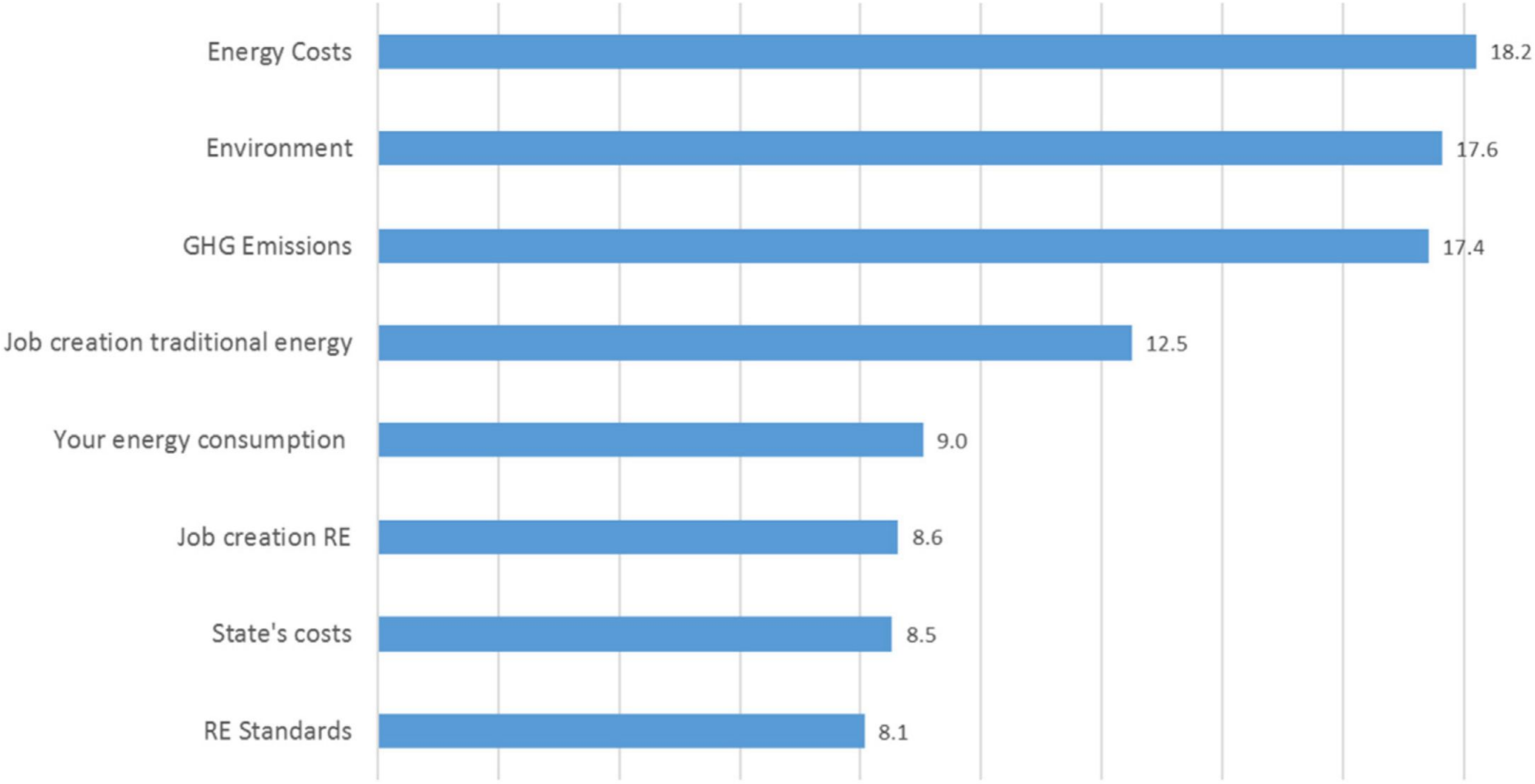
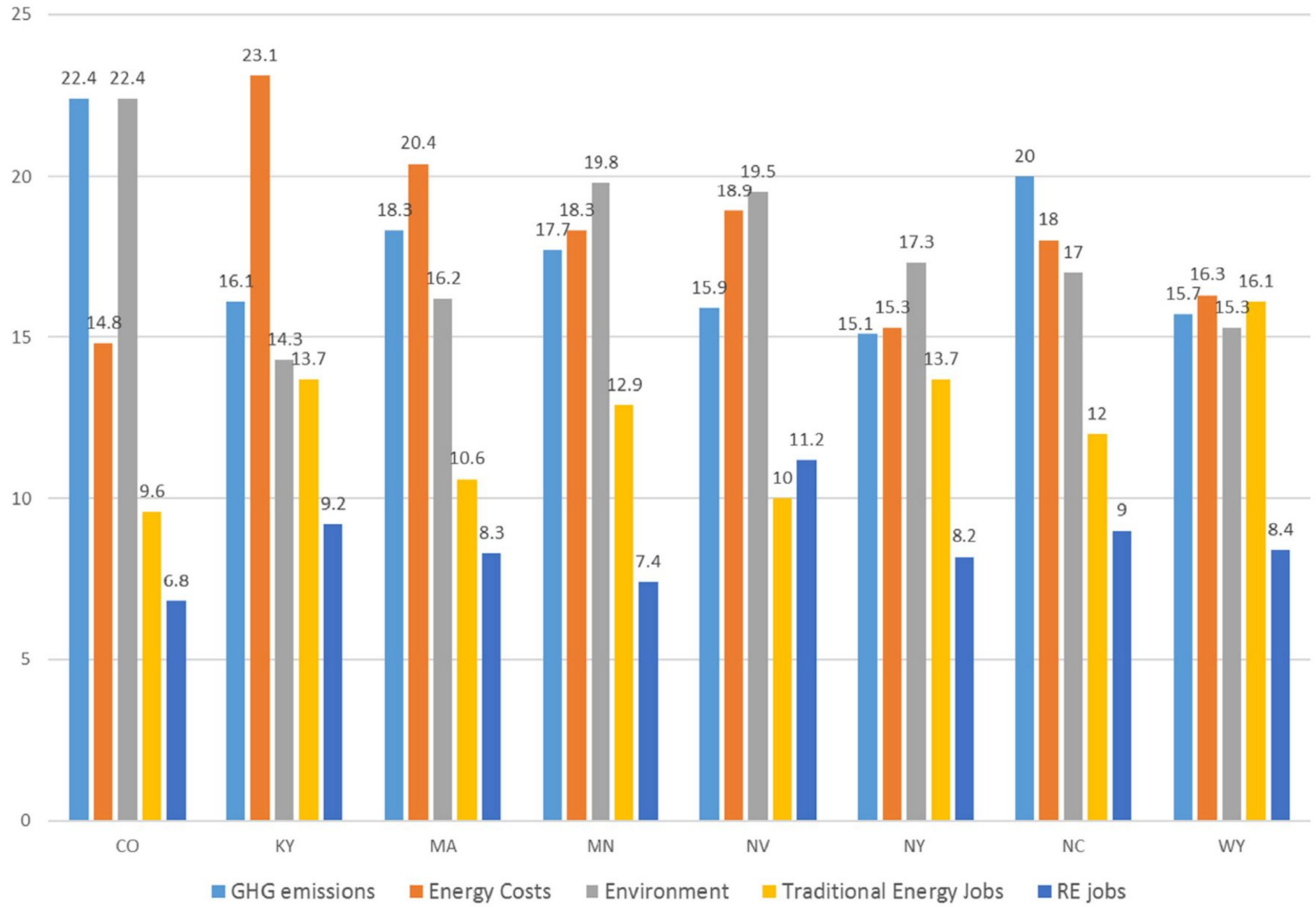


Fig. 3. Eight-State Aggregate of Policy Dimension Importances for Study 2.



25
20
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22.4
14.8
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6.8
23.1
16.1
14.3
13.7
9.2
20.4
18.3
16.2
10.6
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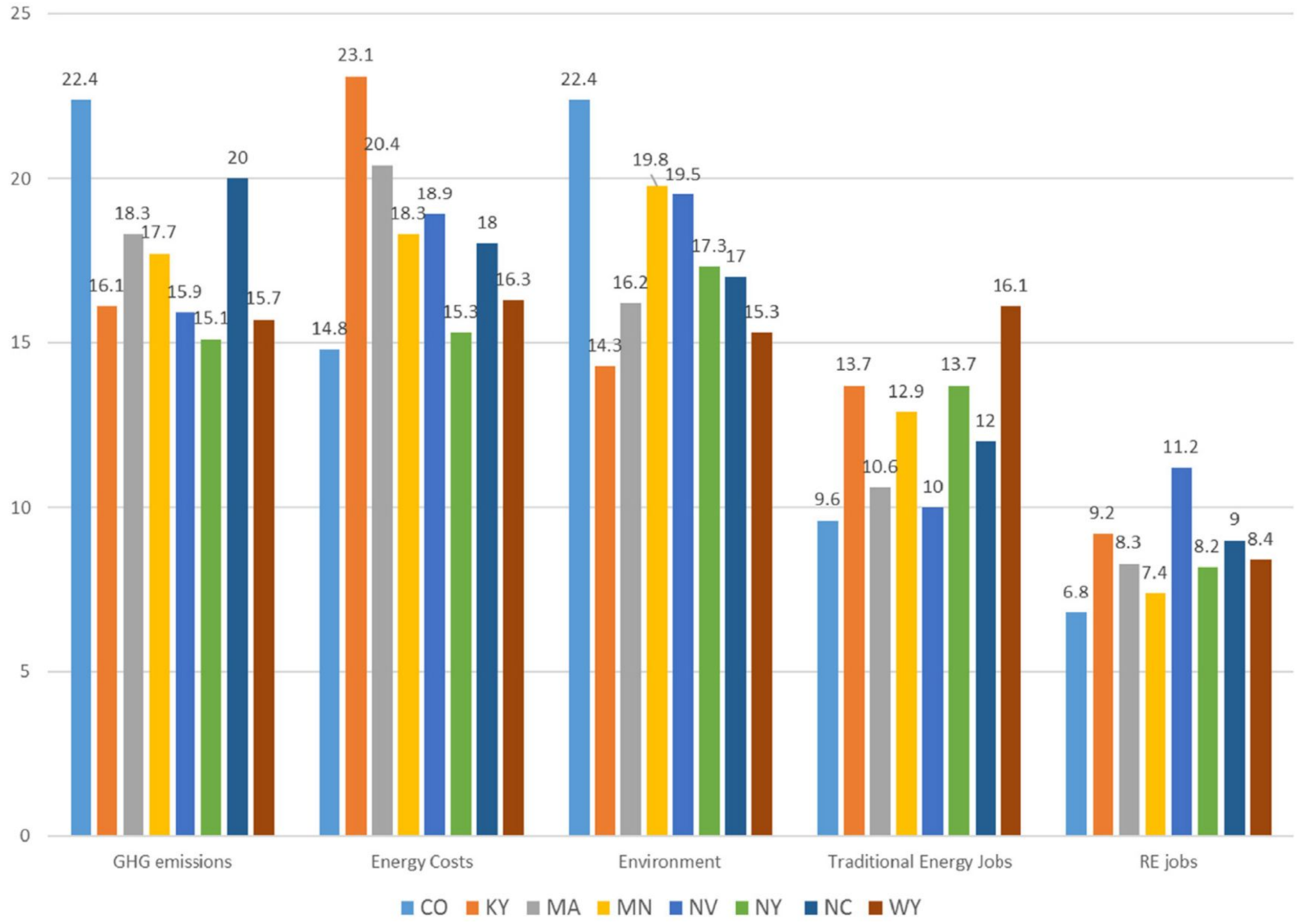
15.3
16.1
8.4
CO
KY
MA
MN
NV
NY
NC
WY
GHG emissions
Energy Costs
Environment
Traditional Energy Jobs
RE jobs



25
20
15
10
5
0
22.4
16.1
18.3
17.7
15.9
15.1
20
15.7
14.8
23.1
20.4
18.3
18.9
15.3
18
16.3
22.4
14.3
16.2
19.8
19.5
17.3
17
15.3
9.6
13.7
10.6
12.9
10
13.7
12
16.1
6.8
9.2
8.3
7.4
11.2
8.2
9
8.4
GHG emissions
Energy Costs
Environment
Traditional Energy Jobs
RE jobs
CO
KY
MA
MN
NV
NY
NC
WY

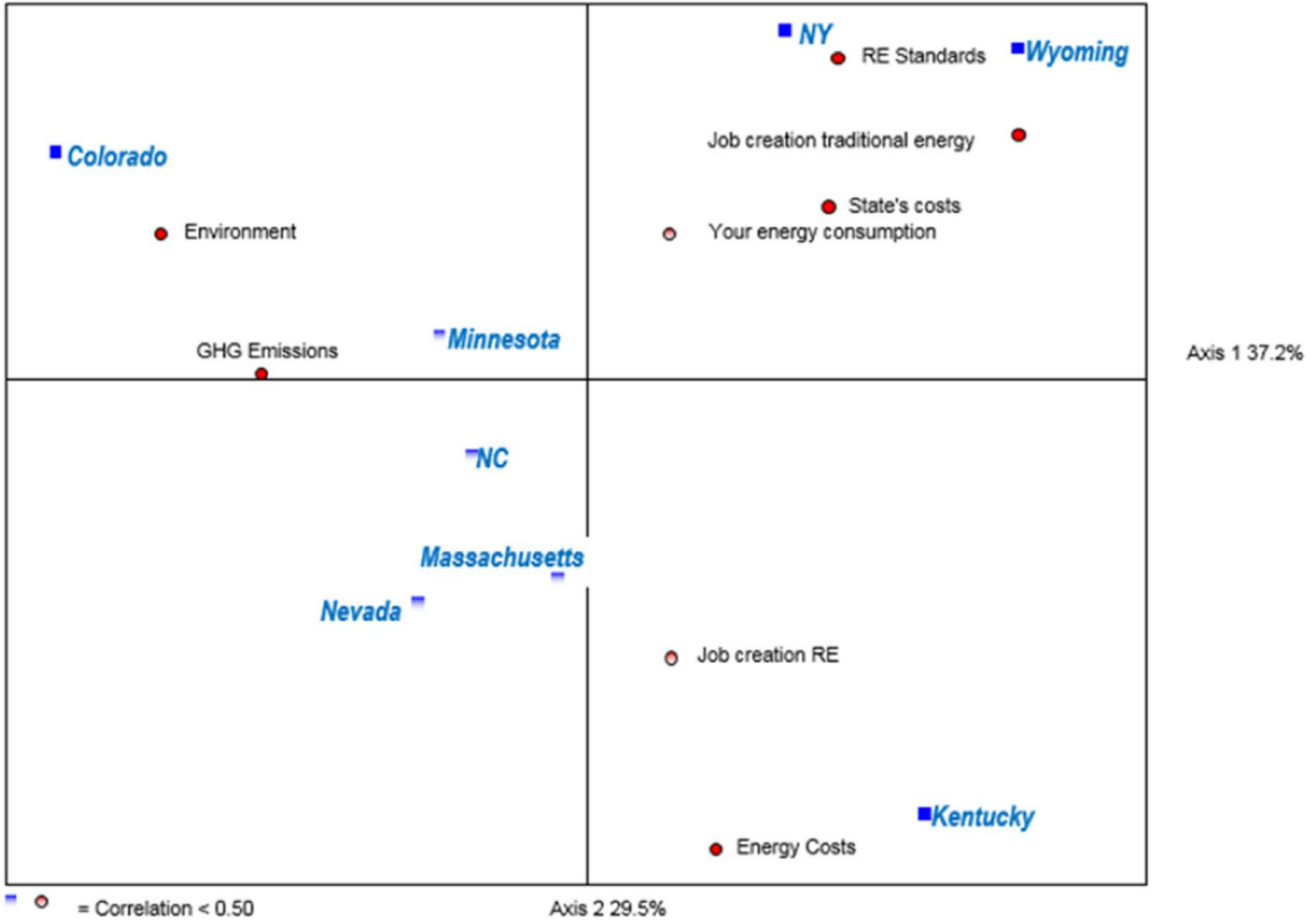


Fig. 5. Correspondence Map of Differences in Importance of Policy Dimensions by State.

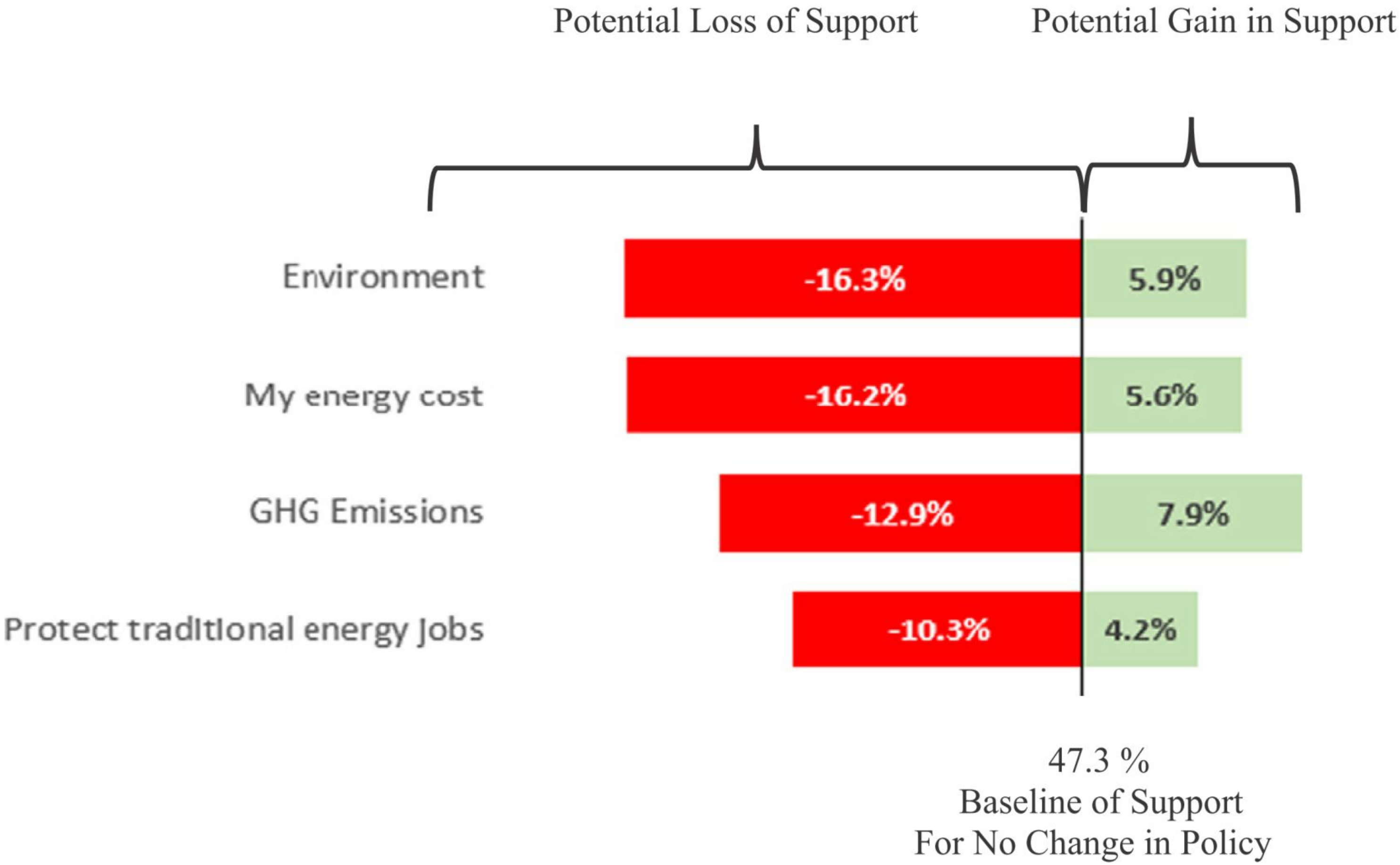


Fig. 6. Impact of Component Changes (Adverse and Positive) from Baseline of Support for No Change in Policy - 8 States.

Energy Tribes

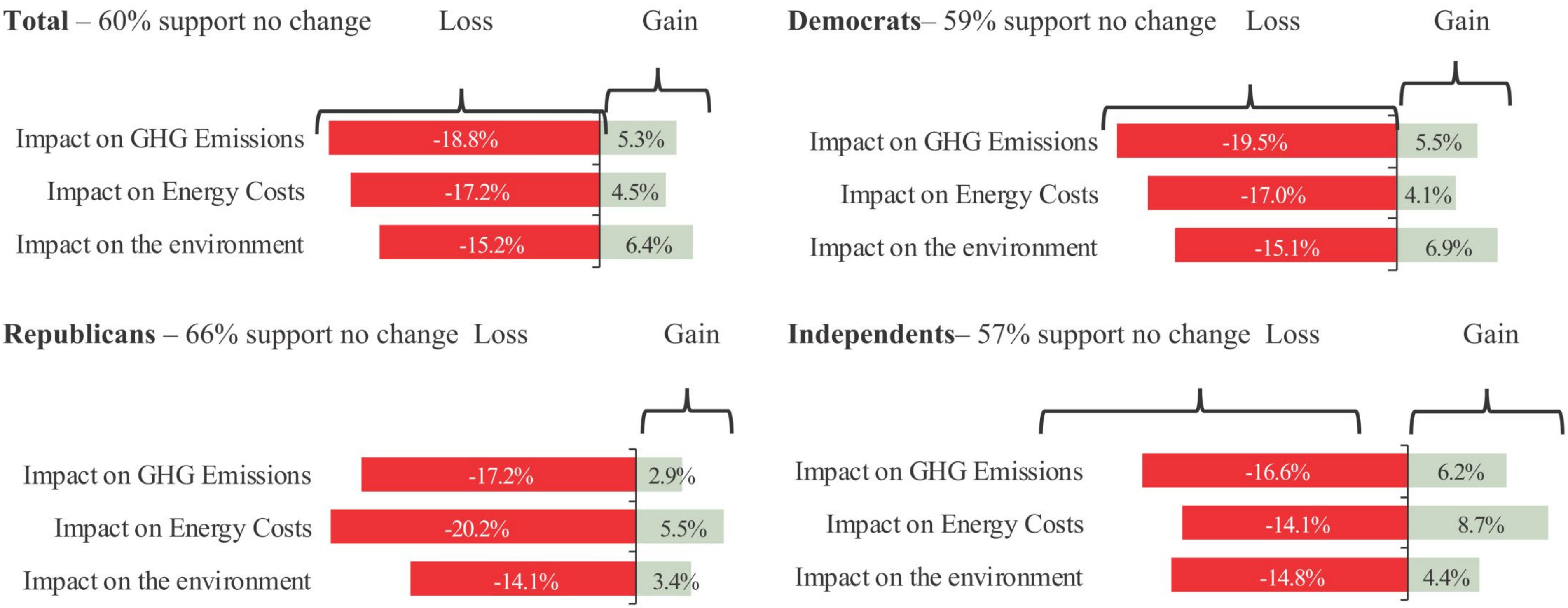


Fig. 7. Impact of Component Changes for North Carolina and for Political-Party Affiliation Groups in the State.

Former Colorado Governor Bill Ritter sees the real leadership for energy policy at the state and local levels now, because most of the skirmishes over energy policies occur at these levels in the current period of legislative gridlock of Washington, DC (Ritter, 2016, p. 193). For example, the three largest sources of greenhouse gas emissions are 1) buildings, 2) transportation systems, and 3) power plants. State and local governments regulate or influence these.

Energy security and the environment

10

10.1 Introduction

All fossil fuels—coal, crude oil, and natural gas—release pollutants into the atmosphere when burned to provide energy. However, natural gas—being composed predominantly of methane which combusts to carbon dioxide and water—is considered the most environment-friendly fossil fuel. It is cleaner burning than coal or petroleum because it contains less carbon than some of its fossil fuel cousins. Natural gas once cleaned (Chapter 7: Process classification and Chapter 8: Gas cleaning processes) also contains much less sulfur and nitrogen compounds than, say coal, and when burned natural gas emits less ash (particulate matter) and soot into the air than coal or petroleum fuels. In fact, among the conventional fossil fuels (coal, crude oil, and natural gas), the consumption growth of natural gas outpaced the other fossil fuel types, i.e., coal and petroleum (BP, 2017). This is attributable to stronger demands of natural gas in industrial and residential heating, increased installations of natural gas-based electric power plants, and new discoveries of large natural gas deposits. In the 21st century, the world already experienced several times significant shortages and price hikes of natural gas, mainly due to imbalances between supply and demand.

Natural gas is the third most used energy source in the United States at 23% of the energy requirements, after crude oil and coal. Industry consumers are, by far, the largest consumer of natural gas in manufacturing goods, followed by utilities for electric power generation, residential consumers for heating homes and cooking, and then commercial users mainly for building heating (Speight and Islam, 2016). Industrial use of natural gas contribute to manufacturing a wide variety of goods including plastics, fertilizers, photographic films, inks, synthetic rubber, fibers, detergents, glues, methanol, ethers, insect repellents, and much more. Natural gas is popularly used in electric power generation. Natural gas burns cleaner and more efficiently than coal. It has less emission-related problems than other popular fossil fuels.

However, natural gas has only a limited market share as a transportation fuel, even though it can be used in regular internal combustion engines. This is mainly due to its low energy density per volume, unless natural gas is compressed under very high pressure. In addition, more than 50% of the residential homes in the United States use natural gas as the main heating fuel. It is obvious that any major disruption in natural gas supply would bring out unique but quite grave consequences in the nation's energy management, at least for a short term and for a certain affected region, since natural gas is heavily utilized by both electric power

Natural Gas. DOI: https://doi.org/10.1016/B978-0-12-809570-6.00010-2

Abstract

As long as many countries have fossil fuel-based economies, fossil fuel combustion will lead to environmental problems. In addition, the venting or leaking of natural gas into the atmosphere can have a significant effect with respect to greenhouse gases because methane, the principal component of natural gas, is much more effective in trapping these gases than carbon dioxide. The exploration, production, and transmission of natural gas, as well, can have adverse effects on the environment.

This chapter addresses the many environmental aspects related to the use of natural gas, including the environmental impact of natural gas relative to other fossil fuels and some of the potential applications for increased use of natural gas. These issues include: (1) greenhouse gas emissions, (2) smog, air quality, and acid rain, and (3) industrial and electric generation emissions.

10.1. Introduction

10.2. Natural gas and energy security

10.2.1. Reserves

10.2.2. Energy security

10.3. Emissions and pollution

10.3.1. Greenhouse gas emissions

10.3.2. Air pollutants

10.3.2.1. Emissions during exploration, production and delivery

10.3.2.2. Emissions during processing

10.3.2.3. Emissions during combustion

10.4. Smog and acid rain

10.5. Natural gas regulations

10.5.1. Historical aspects

10.5.2. Federal regulations

Thus, as with other fuels, natural gas also affects the environment when it is produced, stored, and transported. Because natural gas is made up mostly of methane (another greenhouse gas), there is the potential for leaks of methane into the atmosphere from wells, storage tanks, and pipelines. In addition, exploring and drilling for natural gas will always have some impact on land and marine habitats but new technologies have greatly reduced the number and size of areas disturbed by drilling (often referred to as *environmental footprints*). Satellites, global positioning systems, remote sensing devices, and 3-D and 4-D seismic technologies make it possible to discover natural gas reserves while drilling fewer wells. Plus, use of horizontal drilling and directional drilling make it possible for a single well to produce gas from much bigger areas of the reservoirs (Speight, 2016).

The *Energy Independence and Security Act of 2007* (originally named the *Clean Energy Act of 2007*) is an Act of Congress concerning the energy policy of the United States. The stated purpose of the act is “to move the United States toward greater energy independence and energy security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes.

Thus potential environmental aspects associated with natural gas processing include the following: (1) air emissions, (2) wastewater, (3) hazardous materials, (4) wastes, and (5) noise. In terms of air emissions, fugitive emissions in natural gas processing facilities are associated with leaks in tubing; valves; connections; flanges; packings; open-ended lines; floating roof storage tank, pump, and compressor seals; gas conveyance systems, pressure relief valves, tanks or open pits/containments, and loading and unloading operations of hydrocarbons.

Natural gas is less chemically complex than other fuels, has fewer impurities, and its combustion accordingly results in less pollution. In the simplest case, complete combustive reaction of a molecule of pure methane (CH_4) with two molecules of pure oxygen produces a molecule of carbon dioxide gas, two molecules of water in vapor form, and heat.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Heat}$$

In practice, the combustion process is not always perfect and when the air supply is inadequate, carbon monoxide and particulate matter (soot) are also produced. In the emissions profile of the electric generation industry. Power plants in the United States account for 67% of sulfur dioxide emissions, 40% of carbon dioxide emissions, 25% of nitrogen oxide emissions, and 34% of mercury emissions (National Environmental Trust, 2002, “Cleaning up Air Pollution from America’s Power Plants”). Coal-fired power plants are the greatest contributors to these types of

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

$$2NO + H_2O \rightarrow 2HNO_2$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$NO_2 + H_2O \rightarrow HNO_3$$

Acid rain has a pH less than 5.0 and predominantly consists of sulfuric acid (H_2SO_4) and nitric acid (HNO_3). As a point of reference, in the absence of anthropogenic pollution sources the average pH of rain is −6.0 (slightly acidic; neutral pH = 7.0). In summary, the sulfur dioxide that is produced during a variety of pro-

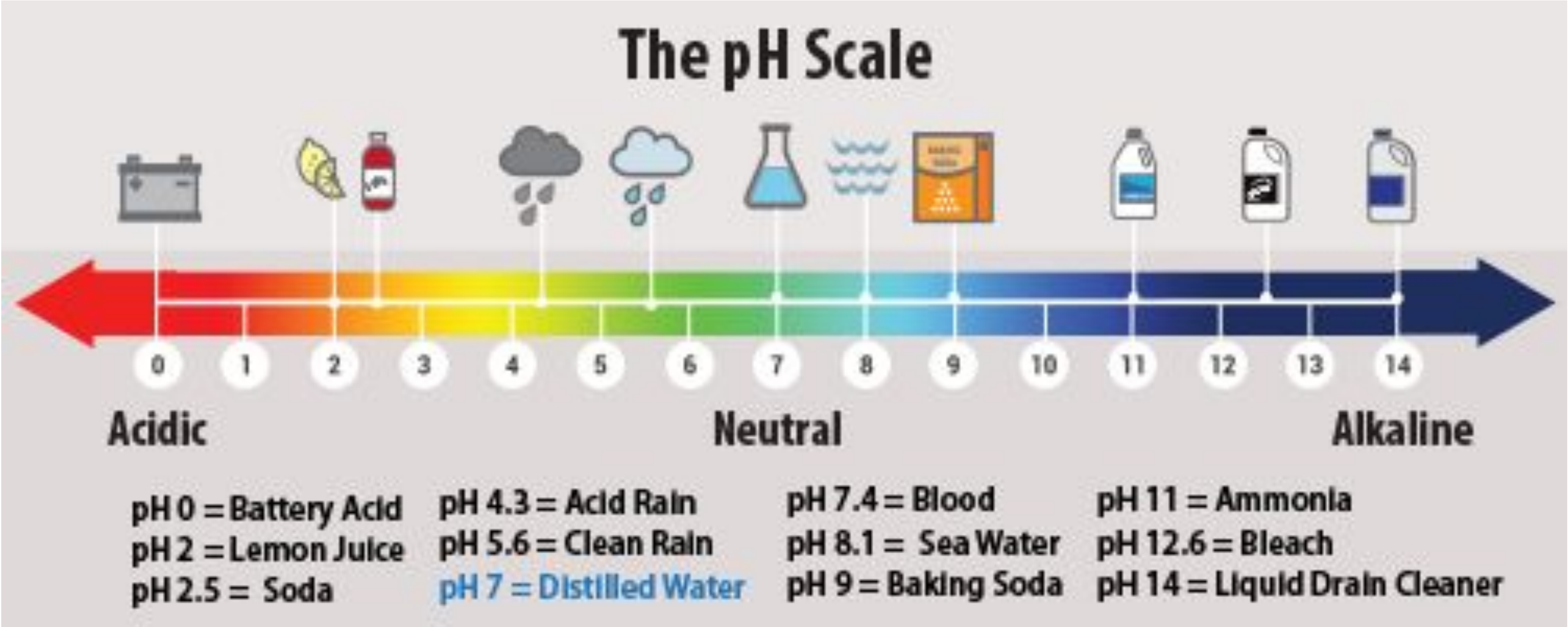

The pH Scale
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Acidic
Neutral
Alkaline
pH 0 = Battery Acid
pH 2 = Lemon Juice
pH 2.5 = Soda
pH 4.3 = Acid Rain
pH 5.6 = Clean Rain
pH 7 = Distilled Water
pH 7.4 = Blood
pH 8.1 = Sea Water
pH 9 = Baking Soda
pH 11 = Ammonia
pH 12.6 = Bleach
pH 14 = Liquid Drain Cleaner

Table 10.1 Examples of Federal Laws (*listed alphabetically*) in the United States to monitor hydraulic fracturing projects

Act	Purpose
Clean Air Act	Limits air emissions from engines, gas processing equipment, and other sources associated with drilling and production
Clean Water Act	Regulation of surface discharges of water associated with natural gas and crude oil drilling and production, as well as storm water runoff from production sites
Energy Policy Act	Exempted hydraulic fracturing companies from some regulations; may disclose chemicals through a report submitted to the regulatory authority but in some instances, chemical information may be exempt from disclosure to the public as trade secrets
NEPA	Requires that exploration and production on federal lands be thoroughly analyzed for environmental impacts
NPDES	Requires tracking of any toxic chemicals used in fracturing fluids
Oil Pollution Act	Regulation of ground pollution risks relating to spills of materials or hydrocarbon derivatives into the water table; also regulated under the Hazardous Materials Transport Act
Safe Drinking Water Act	Directs the underground injection of fluids from natural gas and crude oil activities; disclosure of chemical content for underground injections; after 2005, see Energy Policy Act
TSCA	Suggestion that this act be used to regulate the reporting of hydraulic fracturing fluid information

NEPA, National Environmental Policy Act; *NPDES*, National Pollutant Discharge Elimination System; *TSCA*, Toxic Substance Control Act.

NB: The Fracturing Responsibility and Awareness of Chemicals Act (the FRAC Act) was an attempt to define hydraulic fracturing as a federally regulated activity under the Safe Drinking Water Act; no significant moves or passage of this act at the time of writing (https://www.congress.gov/bill/114th-congress/senate-bill/785/text).