From scenarios to action: How to form effective sustainable energy policies

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- Where I come from (and will be going)
- The results of an energy security index
- Optimal policies for promoting low-carbon energy technologies
- Optimizing energy RD&D

The IEE at Vermont Law School:

- **Energy Security & Justice Program**
  - **Energy Access**
  - **Externalities**
  - **Climate change adaptation**
- **Nuclear Power**
- **Smart Grid**
- **SunShot Solar PV**
- **Renewable Electricity (with CMU)**
- **Energy Efficiency and the EPA**

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DAFA tætner. dæmper. beskytter.
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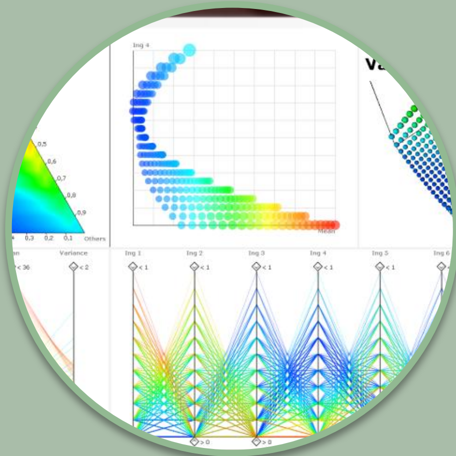


Science

Richard Klein
Sirkku Juhola

Societal dialogue

Björn-Ola Linnér
Jan Ketil Rød

Graduate training

Brynhildur Davidsdottir
Michael Goodsite

The results of an energy security index

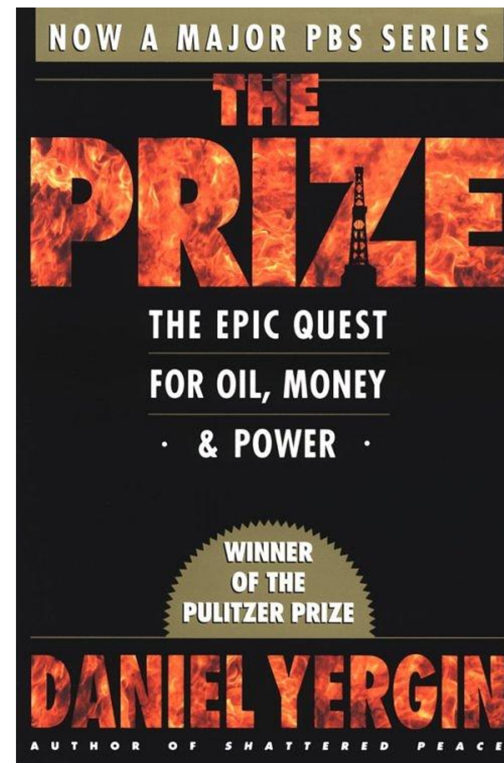
Conceptualizing energy security

- Daniel Yergin
  - Reliable and affordable access to energy supplies
  - Diversification
  - Integration
  - Information

Ensuring Energy Security

Daniel Yergin

From *Foreign Affairs*, March/April 2006



Energy Policy 35 (2007) 2466–2480

ENERGY POLICY

www.elsevier.com/locate/enpol

Energy indicators for tracking sustainability in developing countries

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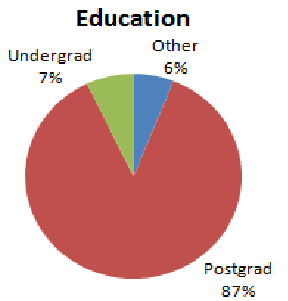
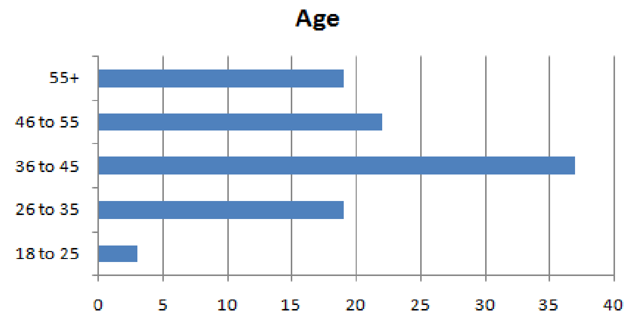
	sustainability criteria	indicator	83/84	88/89	93/94	99/2000	2025 scenario f*	tendency
economy	economic activity	total primary energy consumption [MToe] a*	275.3	333.1	395.8	485.7	1135.8	↗
	efficiency	(energy intensity)$^{-1}$ [million Rs. 93/94/ktoe] a,b*	17.14	18.47	19.74	23.64	69.72	↗
	energy resource stock	ratio of renewable and total energy resources used c*	0.49	0.42	0.40	0.36	0.14	↘
environment	climate change	sum of released CO^2 equivalents due to energy use [MT] c,d*	545	760	865	1075	3550	↗
	local and regional air pollution	fuel based emissions of SOx and NOx [MT] d*	-	3.45 / 2.63	4.51 / 3.45	-	9.49 / 8.04	↗
	indoor air pollution	number of people relying on solid fuels for cooking [million] e*	595	625	622	690	585	↘
society	poverty	access-use matrix poverty rate e*	72.8	60.4	47.2	34.1	23.6	↘
	equity	Gini-Index of access-adj. useful energy e*	0.4	0.485	0.49	0.49	0.49	→

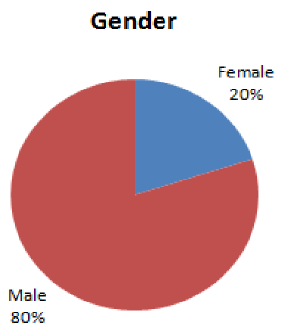
To provide a complete conceptual framework for energy security, we did four things:

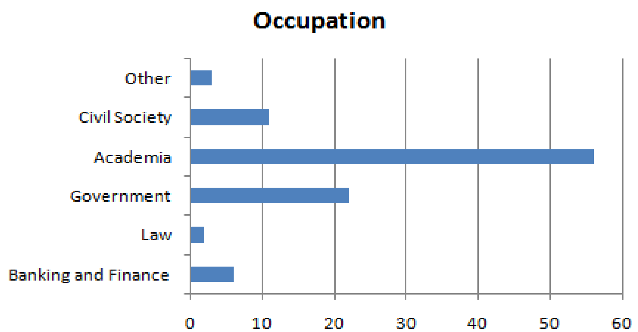
• First, 64 semi-structured research interviews over the course of February 2009 to June 2010, including visits to the International Energy Agency, U.S. Department of Energy, United Nations Environment Program, Energy Information Administration, World Bank Group, Nuclear Energy Agency, and International Atomic Energy Agency

•Second, 74 printed copies of an energy security survey to energy experts working in 15 countries at 35 institutions in Asia, Europe, and North America, and received 70 completed surveys back (for a response rate of 95%)









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• Third, a focused, intensive, three day workshop in Singapore in November 2009
• Workshop hosted 37 participants from 17 countries and was, like the interviews, centered on answering the same three questions.
• The workshop consisted of nine formal sessions—ranging from energy security indicators in use at IIASA and IEA to metrics for affordability, diversification, and energy efficiency—and was structured around intensive two hour discussions among all participants on each topic

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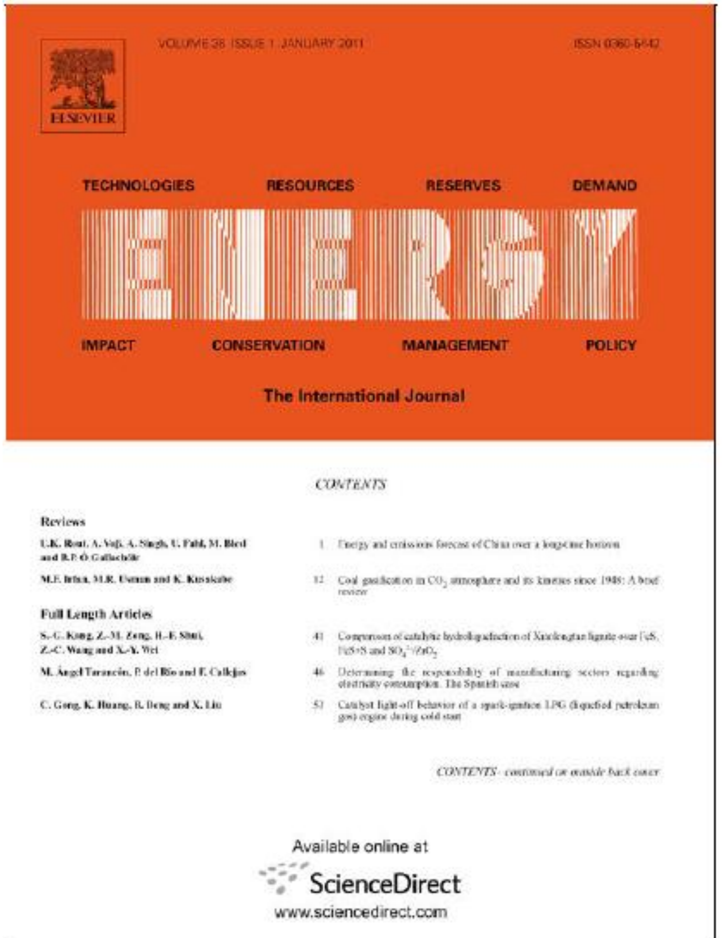
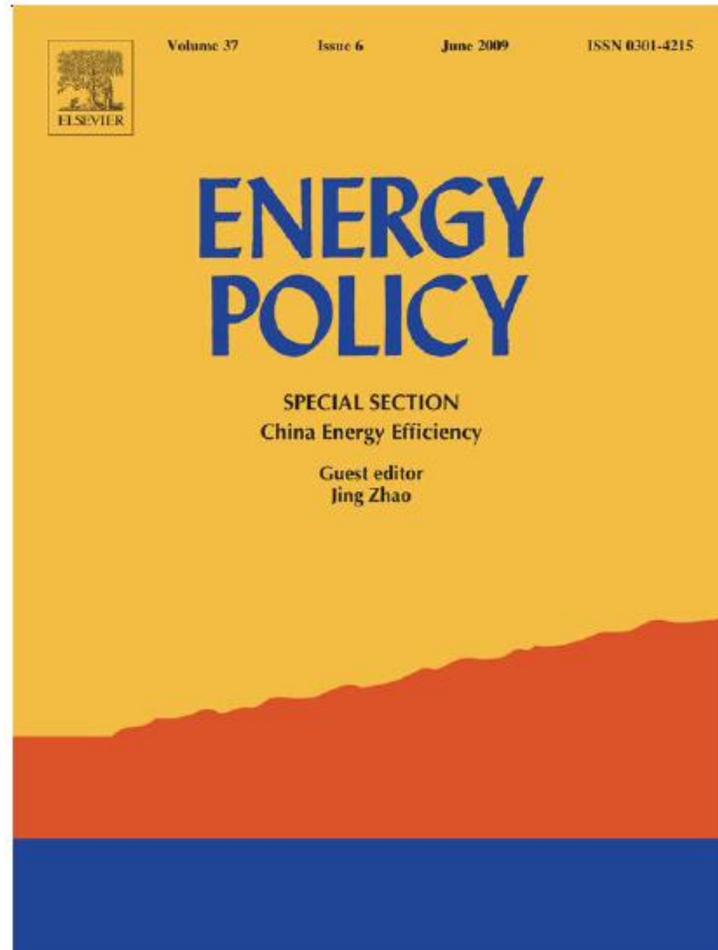
- Fourth, a supplementary literature review of the past 5 years





Our results:

Criteria	Underlying Values	Metrics
Availability	Independence, diversification, reliability	Oil import dependence; Natural gas import dependence; Availability of alternative fuels
Affordability	Equity	Retail electricity prices; Retail gasoline/petrol prices
Energy and Economic Efficiency	Innovation, resource custodianship, minimization of waste	Energy intensity; Per capita electricity use; Average fuel economy for passenger vehicles
Environmental Stewardship	Sustainability	Sulfur dioxide emissions; Carbon dioxide emissions

Source: Sovacool, BK and MA Brown. "Competing Dimensions of Energy Security: An International Review," *Annual Review of Environment and Resources* 35 (November, 2010), pp. 77-108.

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Energy Security Performance Index for 22 OECD Countries, 1970 (in $2007)

	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

Energy Security Performance Index for 22 OECD Countries, 2007

	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

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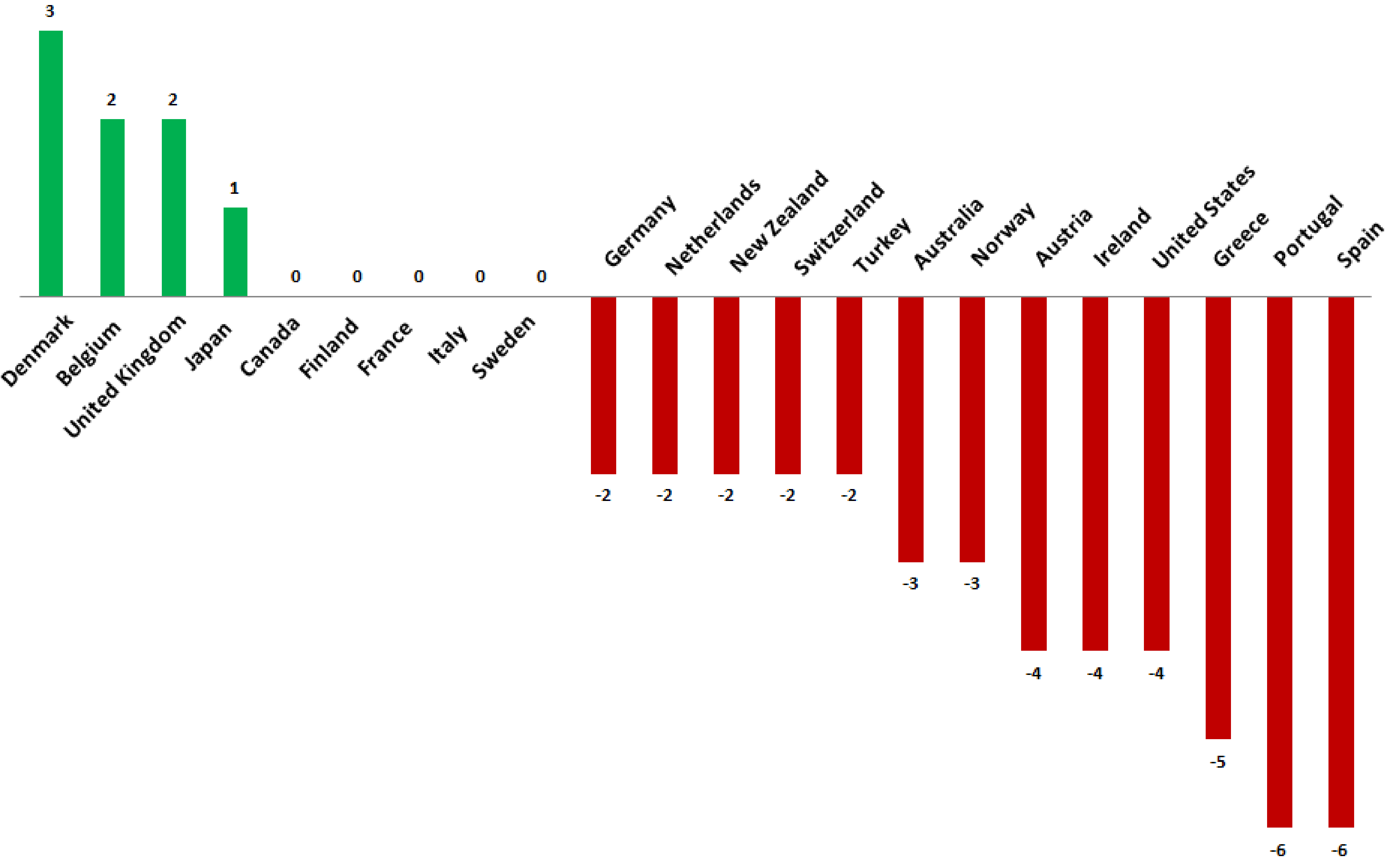
Energy Security Performance Score, 1970 to 2007

	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



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Denmark
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Denmark: The most "energy secure" in OECD

- Denmark has transitioned from being 99 percent dependent on foreign energy sources such as oil and coal to becoming a net exporter of natural gas, oil and electricity today.
- Denmark was (in 2007) the unchallenged world leader in terms of wind energy, exporting $8 billion in wind turbine technology and equipment per year, and Denmark also boasts the lowest energy consumption per capita in the European Union.
- Denmark implemented energy taxes in 1974 as a response to the energy crises, and used the billions in dollars of revenue to invest in wind power, biomass, and small-scale combined heat and power units.
- The government levied a general carbon tax on all forms of energy and set strict vehicle fuel economy standards, and later adopted European standards pledging to decrease carbon dioxide emissions from automobiles.
- Electricity prices are the highest in the European Union at about 38 cents per kWh, and the price of petrol is more expensive than 13 other OECD countries. (Tradeoff with affordability.)

Spain: Tied with Portugal for least "energy secure" in OECD

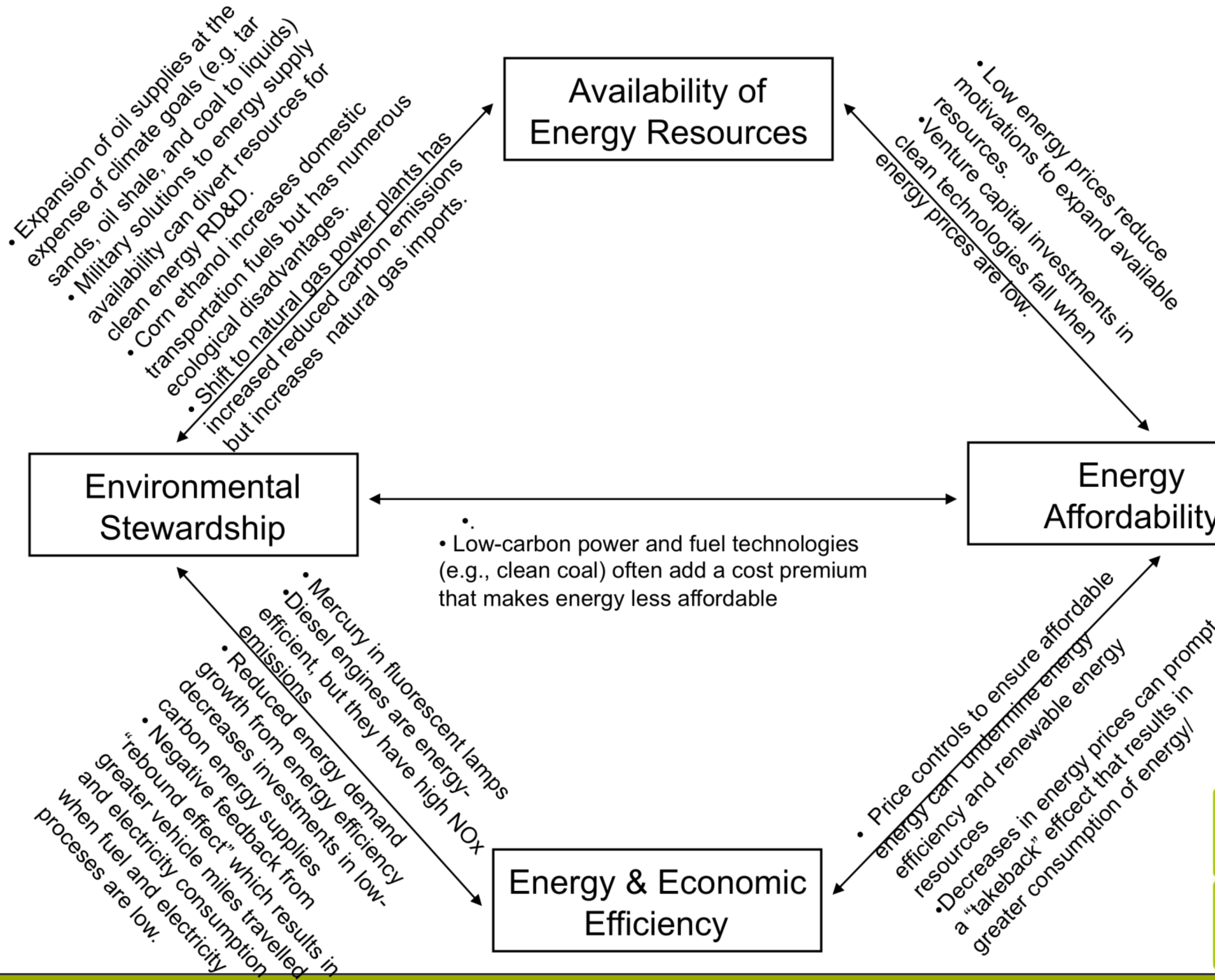
- The energy intensity of Spain's economy has increased, while it has shrunk for 19 of the OECD countries by an average of a third. Spain has not emphasized the efficient use of energy.
- Spain is heavily dependent on imported coal, oil, and natural gas, and has been unable to constrain its GHG emissions and high prices.
- During the 1970s, bankers and industrial managers played the primary role in Spanish energy policymaking. Rather than promote energy efficiency or diversification, these stakeholders sought ways to maintain economic growth and retain political power.
- Spanish regulators heavily focused on building nuclear plants in the early 1980s, but their plans were threatened by high costs and the Chernobyl disaster in 1986.
- The consolidation and concentration of Spanish energy companies, coupled with comparatively weak political oversight and lack of competition has left little space for consumer advocacy or environmental policy.

Preliminary findings (3):

- (1) Despite the near universal deterioration of energy security, a great disparity exists between countries. Top performers
  - Did not rely on the market alone;
  - Implemented a progression of policies: first came energy taxes, standards, and R&D, followed by mechanisms such as tariffs and quotas, demonstrating the necessity of using a variety of mechanisms at once to promote sound energy policy;
  - Remained consistent

- (2) The relative success of Denmark and the relative failure of Spain serve as an important reminder that creating energy security is as much a matter of policy from within as it is from without.

• (3) Tradeoffs between dimensions



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Optimal policies for promoting low-carbon energy technologies

Table 6.5
Enacted policies for promoting renewable energy as of 2010.

	Feed-in tariff	Renewable portfolio standard/quota	Capital subsidies, grants, rebates	Investment or other tax credits	Sales tax, energy tax, excise tax, or vat reduction	Tradable re certificates	Energy production payments or tax credits	Net metering	Public investing, loans, or financing	Public competitive bidding
European Union										
Austria	×		×	×		×			×	
Belgium		*	×	×	×	×		×		
Bulgaria	×		×						×	
Cyprus	×		×							
Czech Republic	×		×	×	×	×		×		
Denmark	×		×	×	×	×		×	×	×
Estonia	×		×		×		×			
Finland	×		×		×	×	×			
France	×		×	×	×	×			×	×
Germany	×		×	×	×			×	×	
Greece	×		×	×				×	×	
Hungary	×		×	×	×				×	×
Ireland	×		×	×		×				×
Italy	×	×	×	×	×	×		×	×	
Latvia	×				×				×	×
Lithuania	×		×	×	×				×	
Luxembourg	×		×	×	×					
Malta			×		×			×		
Netherlands			×	×	×	×	×			
Poland		×	×		×	×			×	×
Portugal	×		×	×	×				×	×
Romania		×			×	×			×	
Slovakia	×			×	×				×	
Slovenia	×		×	×	×	×			×	×
Spain	×		×	×	×	×			×	
Sweden		×	×	×	×	×	×		×	
United Kingdom	×	×	×		×	×			×	
Other developed/transition countries										
Australia	*	×	×		×	×			×	
Belarus									×	
Canada	*	*	×	×	×			×	×	×
Israel	×				×					×
Japan	×	×	×	×		×		×	×	
Macedonia	×									
New Zealand			×			×			×	
Norway			×		×	×			×	
Russia			×							
Serbia	×									
South Korea	×		×	×	×				×	
Switzerland	×		×		×					
Ukraine	×									
United States	*	*	×	×	*	*	×	*	*	*
Developing countries										
Algeria	×			×	×					
Argentina	×		×	*	×		×		×	×
Bolivia					×					
Brazil				×					×	×
Chile		×	×	×	×				×	×
China	×	×	×	×	×		×		×	×
Costa Rica							×			
Dominican Republic	×		×	×	×					
Ecuador	×			×						
Egypt					×					×
El Salvador				×	×				×	
Ethiopia					×					
Ghana			×		×				×	

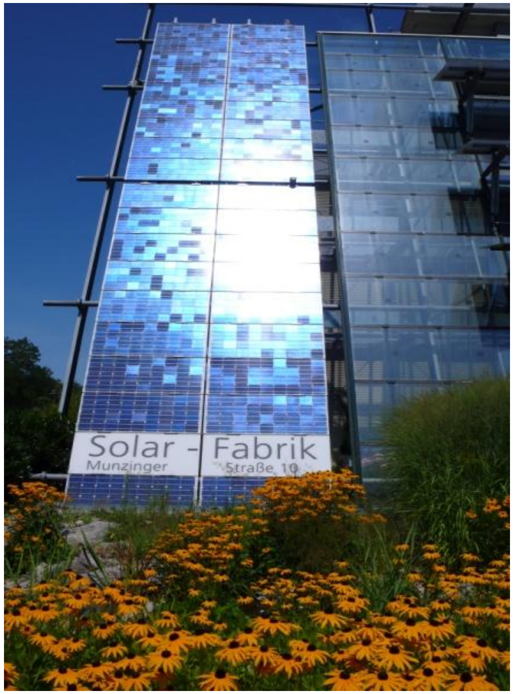
Table 6.5
(continued)

	Feed-in tariff	Renewable portfolio standard/quota	Capital subsidies, grants, rebates	Investment or other tax credits	Sales tax, energy tax, excise tax, or vat reduction	Tradable re certificates	Energy production payments or tax credits	Net metering	Public investing, loans, or financing	Public competitive bidding
Guatemala				×	×					
India	*	*	×	×	×	×	×		×	
Indonesia	×			×	×					
Iran				×			×			
Jordan					×			×	×	
Kenya	×			×						
Malaysia									×	
Mauritius			×							
Mexico				×				×	×	×
Mongolia	×									×
Morocco				×	×				×	
Nicaragua	×			×	×					
Pakistan	×							×		
Palestinian Territories					×					
Panama							×			
Peru				×	×		×			×
Philippines	×	×	×	×	×		×	×	×	×
Rwanda									×	
South Africa	×		X		×				×	×
Sri Lanka	×									
Tanzania	×		×		×					
Thailand	×				×				×	
Tunisia			×		×				×	
Turkey	×		×							
Uganda	×		×		×				×	
Uruguay		×								×
Zambia					×					

*In these countries, some states or provinces have policies but there is no national-level policy.

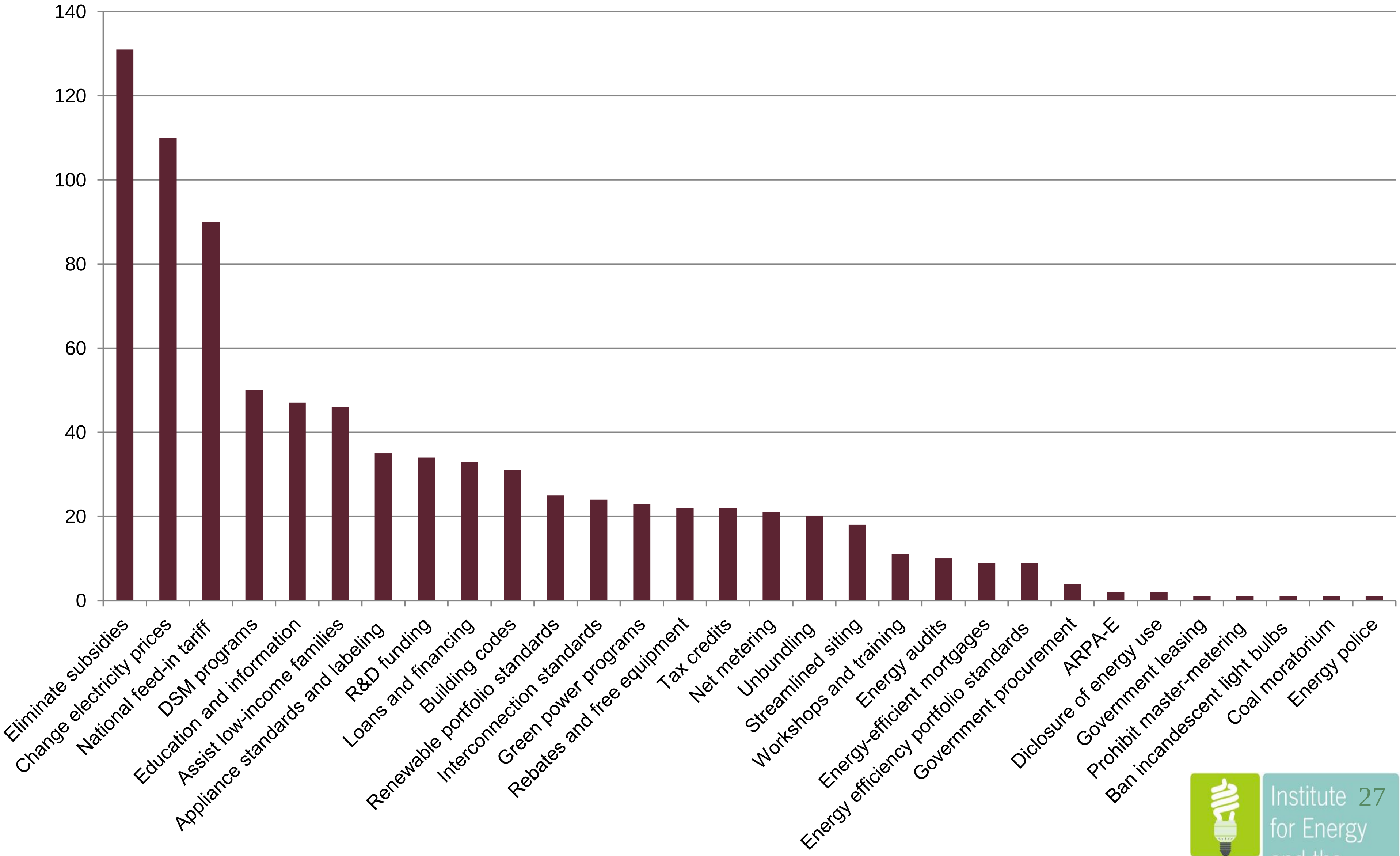
The study we did:

• Relied on a case study, semi-structured research interview approach (modified "Delphi method"), ethnographic, grounded, critical stakeholder analysis methodology with a purposive sample
• Produces "rich" "thick" and "qualitative" descriptions irreducible to numerical variables
•180+ research interviews, 93 institutions, 13 countries, three years (also part of my dissertation)



"What can be done to overcome the impediments facing renewable energy and energy efficiency?"

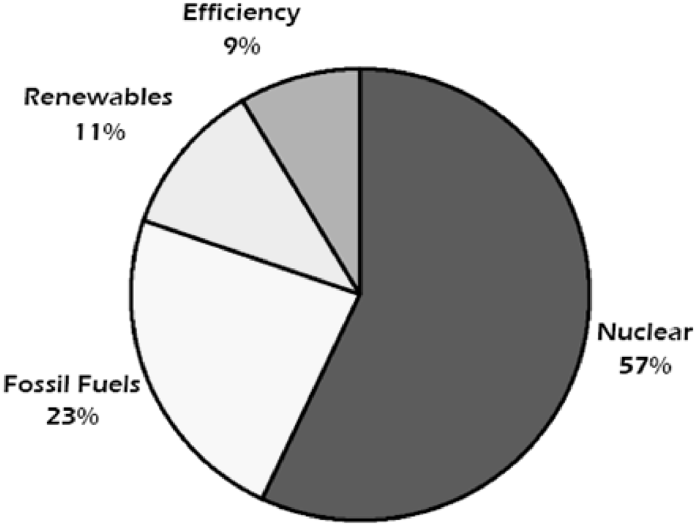
Mechanism	Number of Supporters	% Overall Support
Eliminate subsidies	131	72
Create accurate electricity prices and encourage feedback	110	61
Pass a national feed-in tariff	90	50
Enact a systems benefit charge (to fund energy efficiency)	50	28
Enact a systems benefit charge (to educate the public and disseminate information)	47	26
Enact a systems benefit charge (to assist low-income families)	46	25
Strengthen appliance standards / product labeling	35	19
Increase funding for energy R&D	34	19
Offer low-interest loans and/or government financing	33	18
Implement stricter building codes	31	17
Pass a renewable portfolio standard	25	14
Interconnection standards	24	13
Green power programs	23	13
Offer rebates and/or free energy-efficient equipment	22	12
Extend and bolster tax credits	22	12
Net metering	21	12
Unbundling of generation, transmission, and distribution	20	11
Streamlined permitting and siting	18	10
Offer workshops and training seminars	11	6
Government sponsored energy audits	10	6
Energy-efficient mortgages	9	5
Energy efficiency portfolio standards	9	5
Government procurement	4	2
Create and fund an Advanced Research Projects Agency-Energy	2	1
Force building managers to disclose energy use	2	1
Provide leases on government land	1	<1
Prohibit master-metering in apartment complexes	1	<1
Ban incandescent light bulbs	1	<1
Coal moratorium	1	<1


140
120
100
80
60
40
20
0
Eliminate subsidies
Change electricity prices
National feed-in tariff
DSM programs
Education and information
Assist low-income families
Appliance standards and labeling
R&D funding
Loans and financing
Building codes
Renewable portfolio standards
Interconnection standards
Green power programs
Rebates and free equipment
Tax credits
Net metering
Unbundling
Streamlined siting
Workshops and training
Energy audits
Energy-efficient mortgages
Energy efficiency portfolio standards
Government procurement
ARPA-E
Diclosure of energy use
Government leasing
Prohibit master-metering
Ban incandescent light bulbs
Coal moratorium
Energy police

#1: Remove Subsidies

- End-use energy efficiency has received $1 in subsidies for every $35 spend on oil, gas, and coal subsidies granted between 1943 and 1998
- From 2002 to 2007, nuclear power received half of all OECD subsidies, fossil fuels 27 percent, renewable energy 12 percent
- Limited liability for nuclear accidents estimated at more than all energy R&D expenditures
- Nuclear power development received subsidies worth $15.30 per kWh between 1947 and 1961, which compares with subsidies worth only $7.19 per kWh for solar and 46 cents per kWh for wind between 1975 and 1989

U.S. Department of Energy Budget Expenditures on R&D, 1947 to 1997



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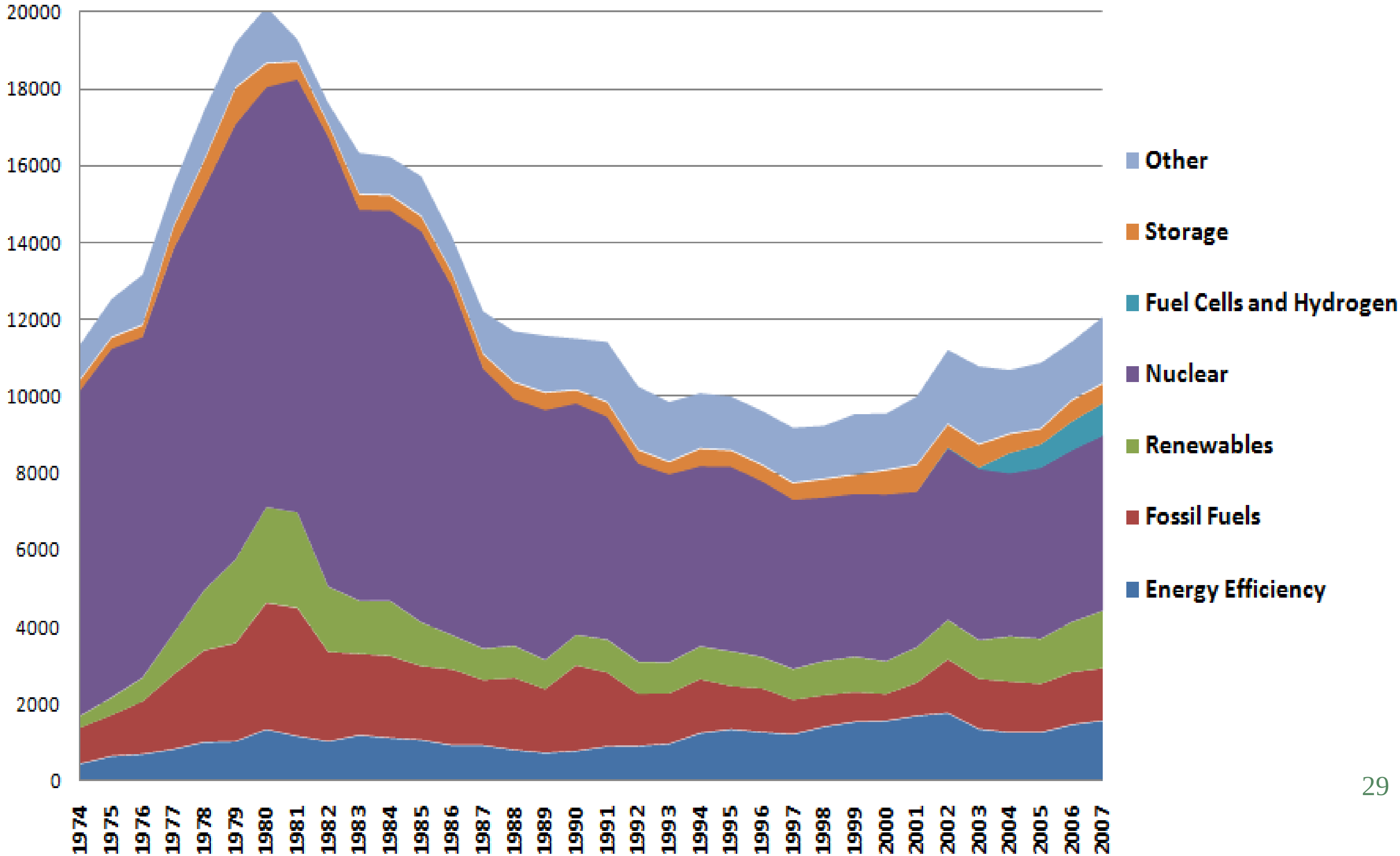
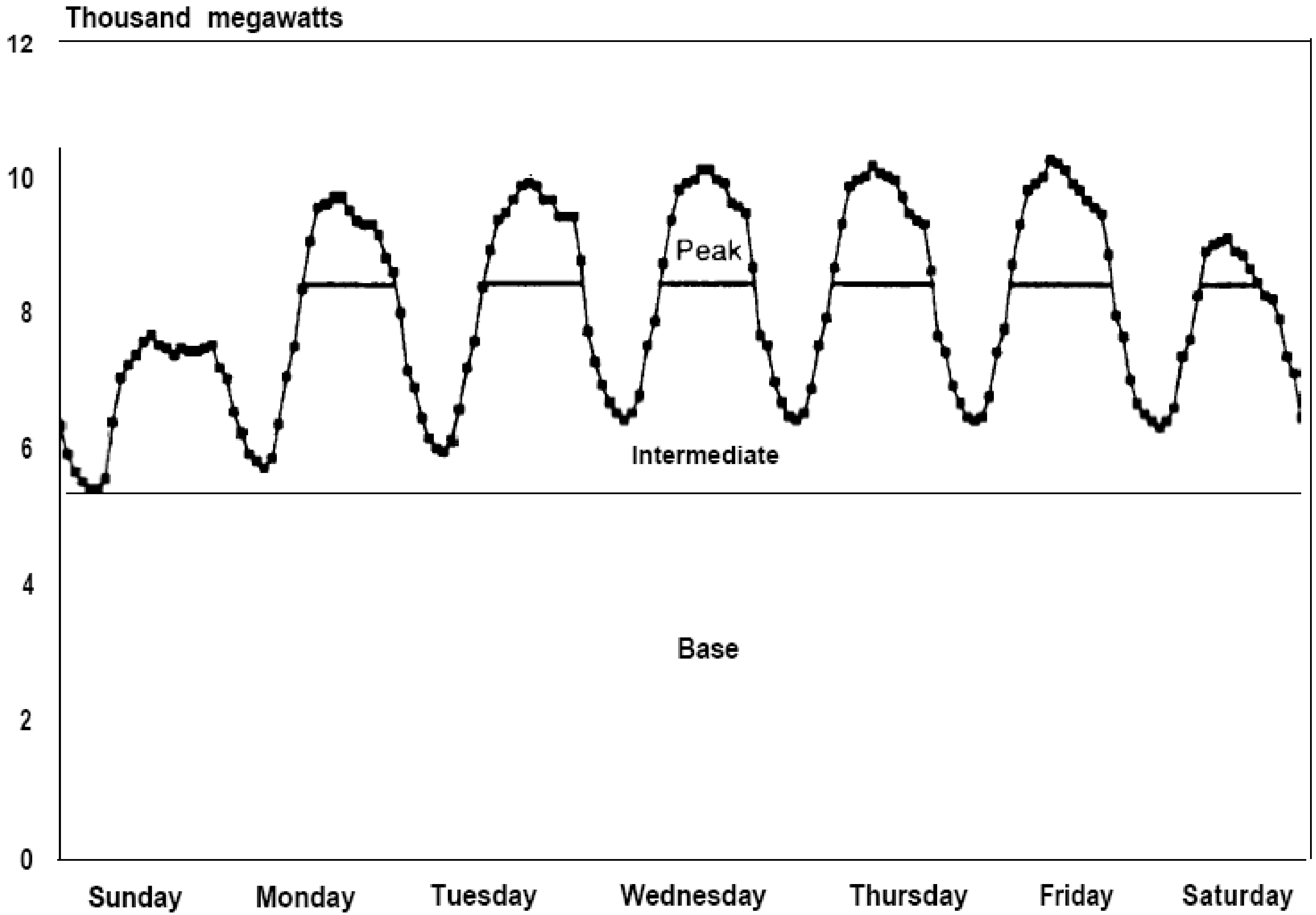
Global energy R&D expenditures, 1974–2007 (millions of US Dollars)



#2: Change prices (by reflecting time of use)

Weekly Load Profile for a Typical Electric Utility



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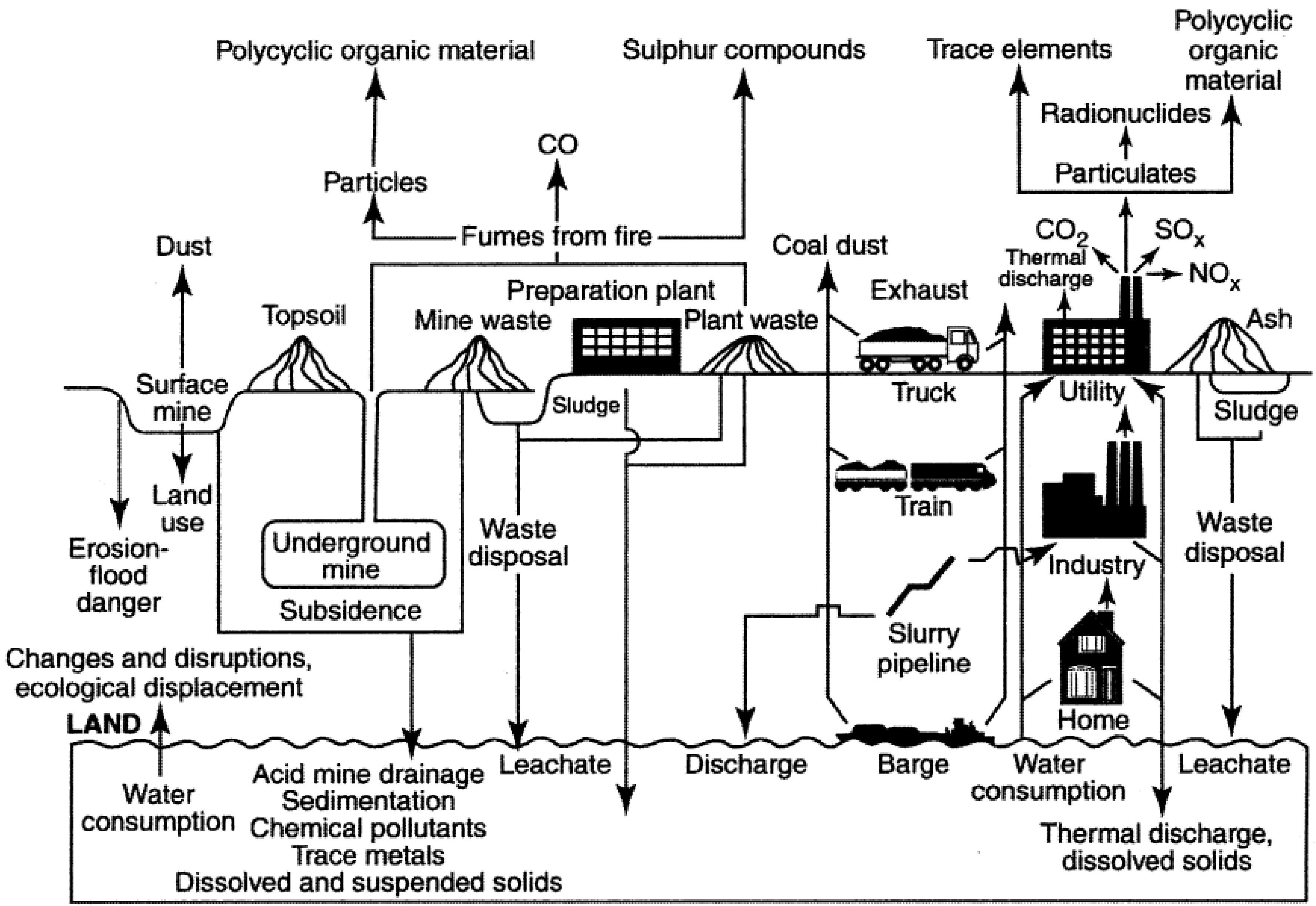
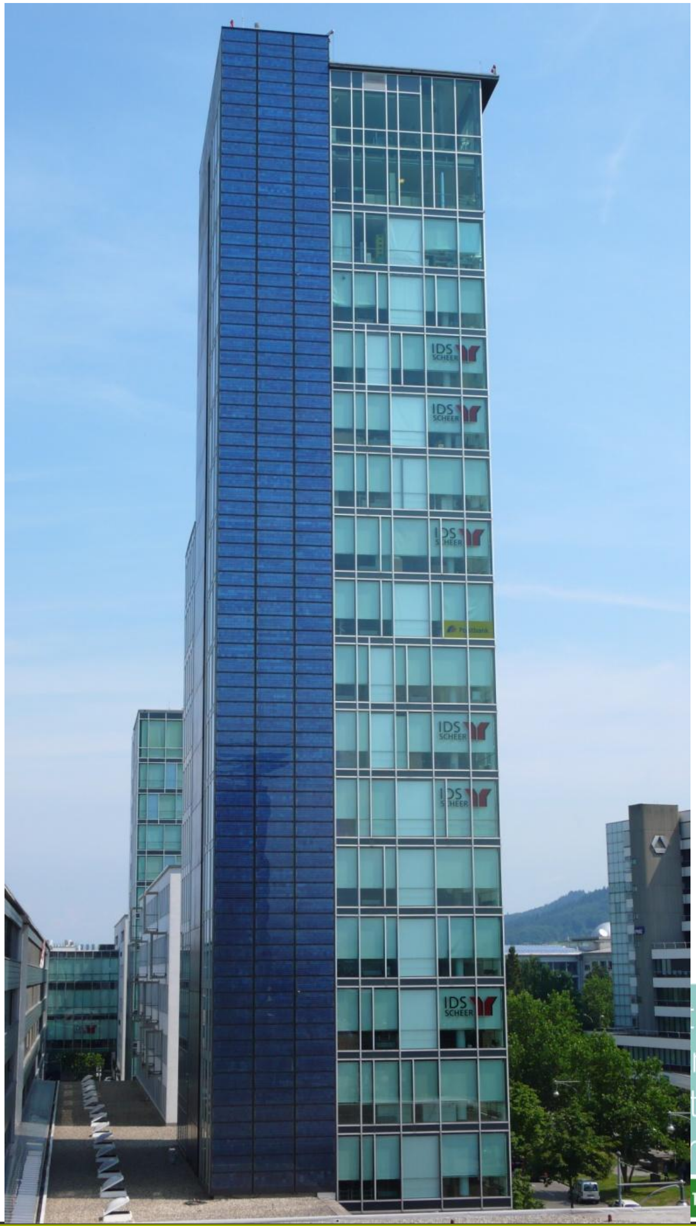
#2 Change Prices (by internalizing externalities)



#3: pass national feed-in tariffs

- Feed-in tariffs (FITs) set a fixed price for utility purchases of renewable energy
- Rates are usually set at a "premium" and above retail prices to incentivize investment in renewable energy
- The first FIT was (arguably) the U.S. PURPA of 1978 or Germany's electricity Feed-In Law in 1991
- FITs are sometimes called "fixed price policies," "standard offer contracts," "feed-in laws," "renewable energy payments," and "advanced renewable tariffs



Successful FITs have the following 8 core characteristics:

(1) They provide a fixed price contract, which can be an all inclusive rate or a fixed premium on top of existing market prices for electricity, over a long period of time (usually the reasonable life of a system, or 15–30 years).

(2) The costs of these higher tariffs are distributed to all electricity consumers, not tax payers

(3) Contracts are designed to cover investment costs and a modest return of 5–6 percent (usually working backwards)

(4) Utilities are obligated to purchase the power produced from renewable resources even if they do not need it, and tariffs are paid irrespective of the owner's actual power consumption.

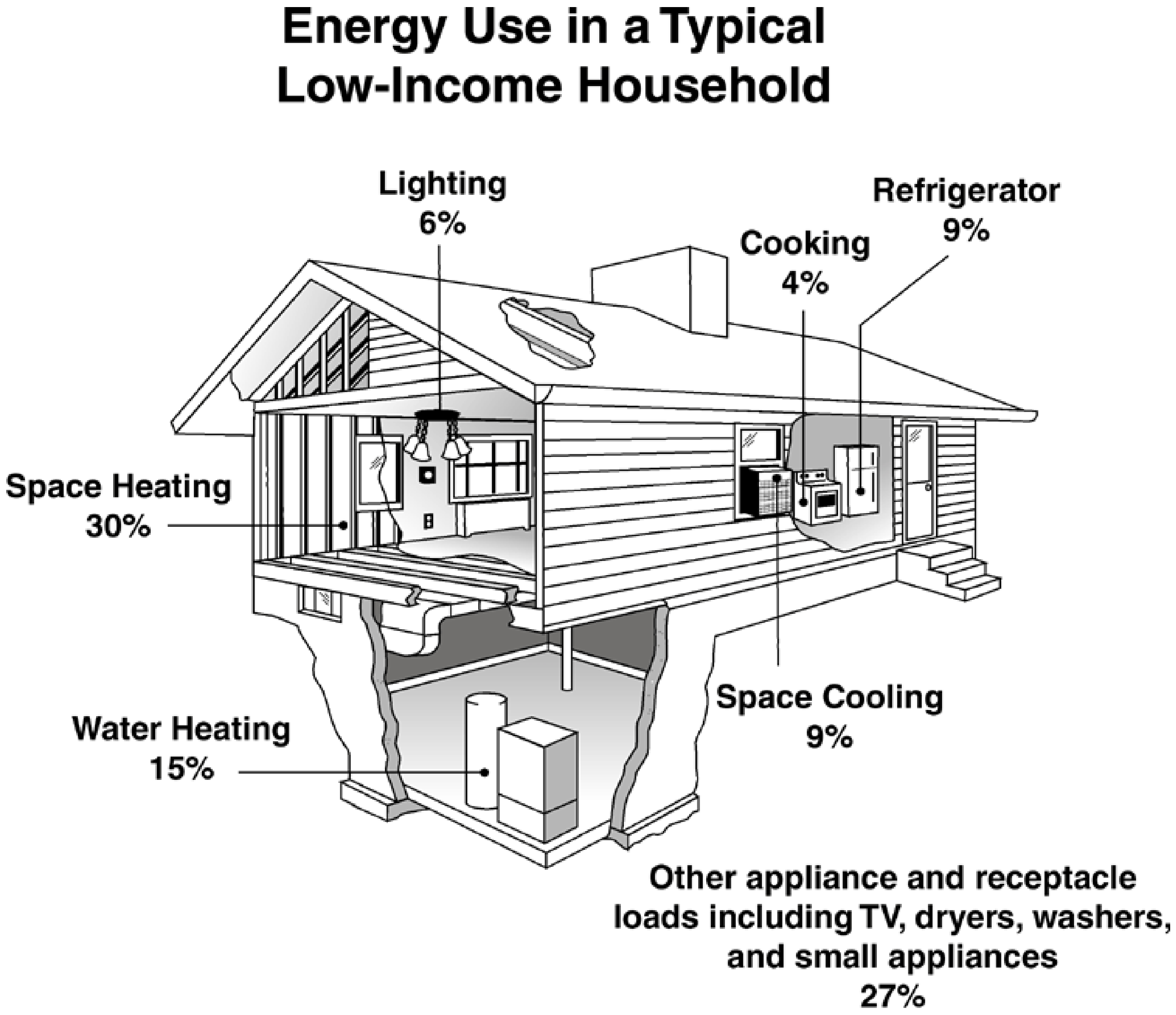
(5) Network and transmission operators must provide those wishing to take advantage of the tariffs access to the grid, sometimes giving them priority access.

(6) Schemes decrease tariff prices each year (something known as "degression" or "stepped tariffs") to reduce costs

(7) FITs are differentiated by type, project size, location, and resource quality

(8) FITs set no restrictions on eligibility or capacity (meaning they can be residential and commercial)

#4: Systems benefits charge: protect the poor



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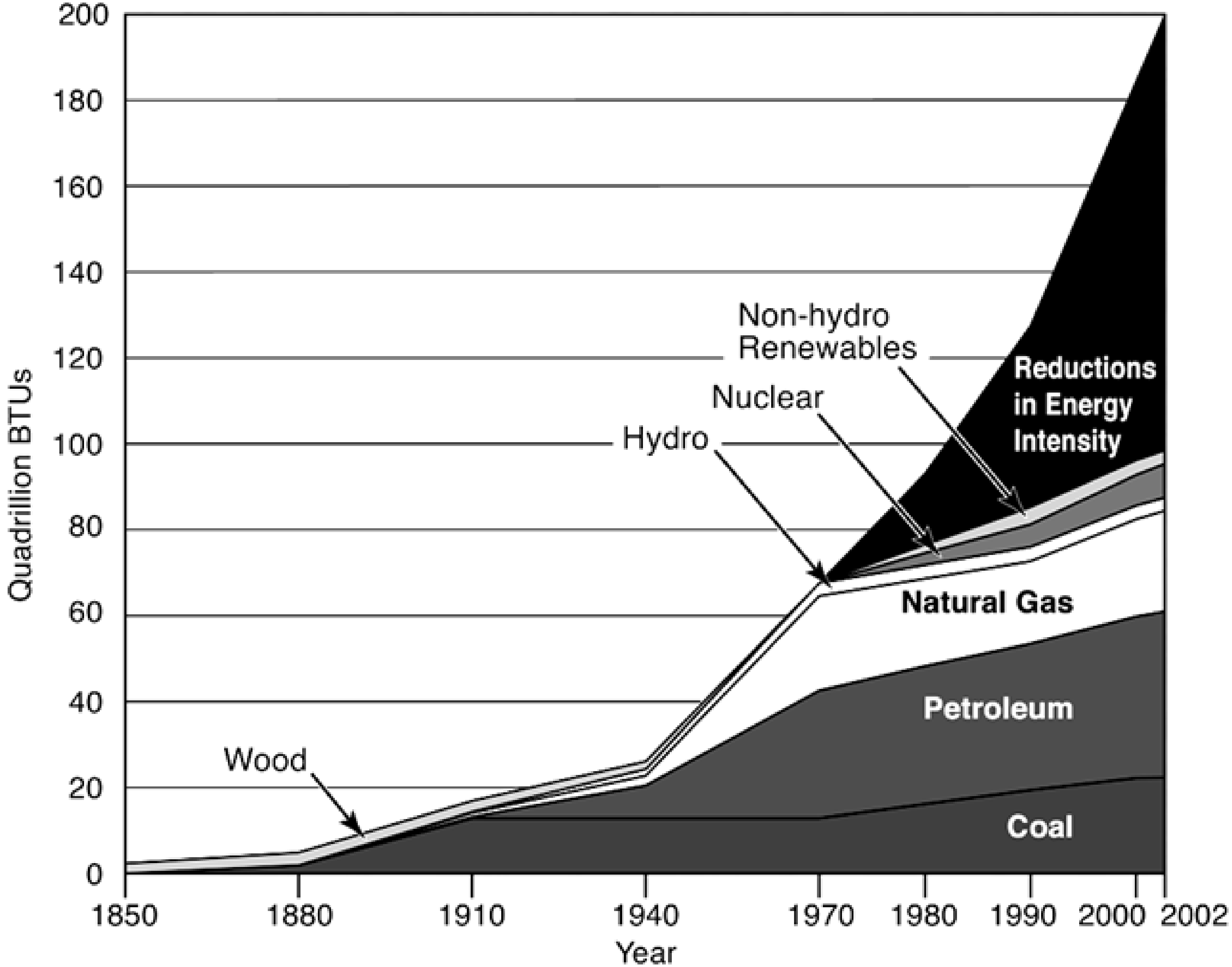
#4: systems benefits charge: fund energy efficiency

Energy sources in the United States, 1850 to 2002



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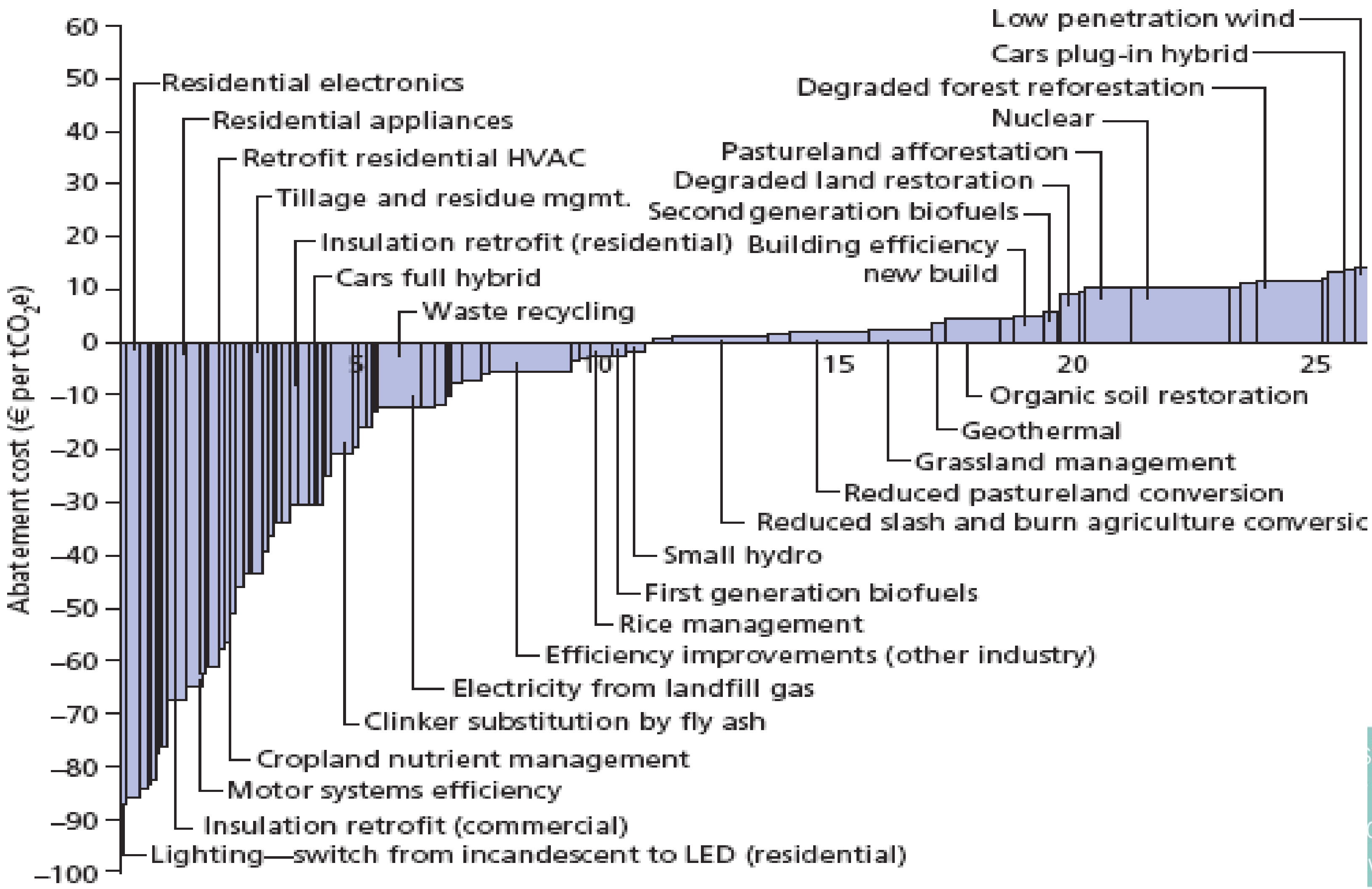
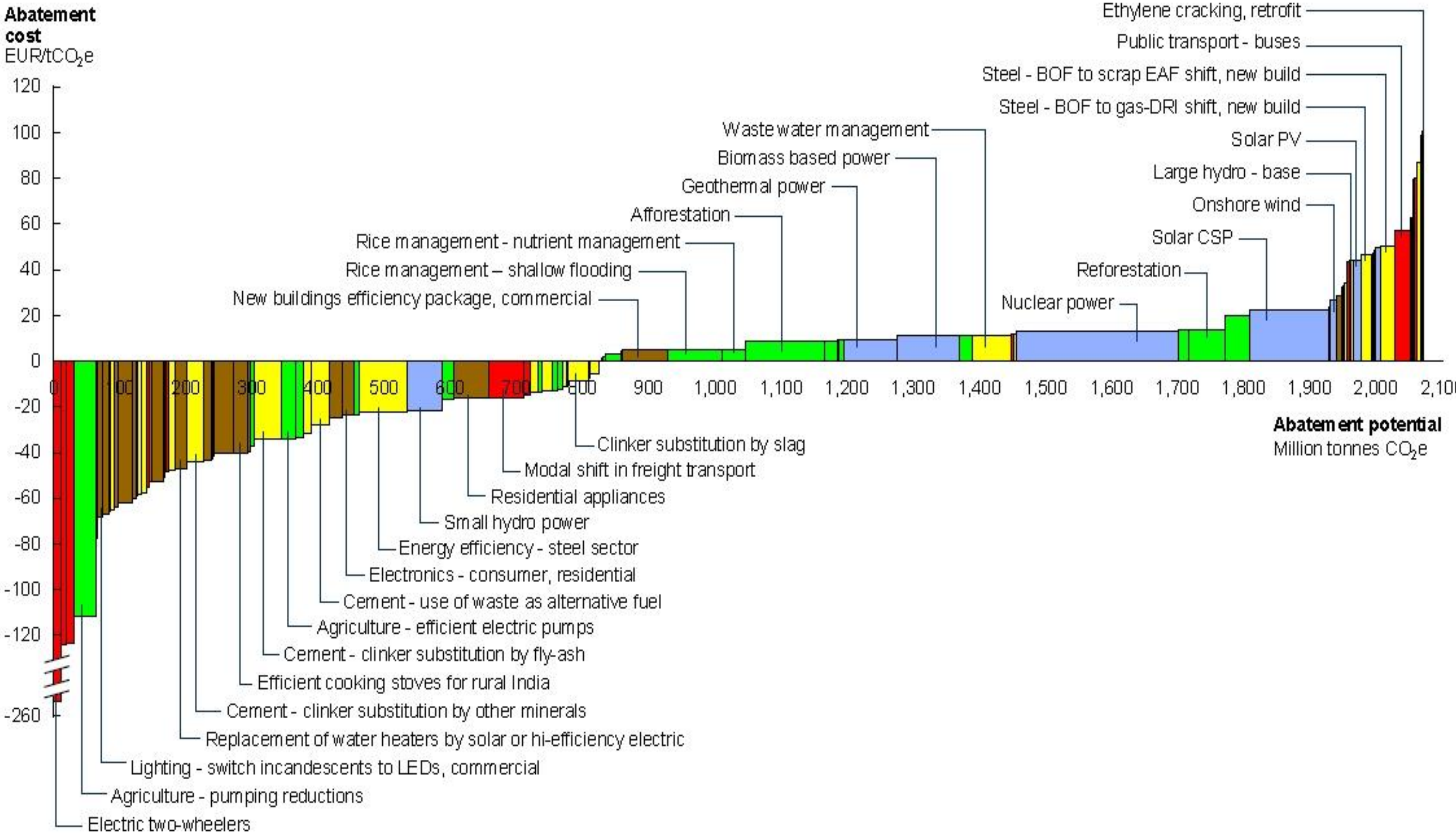
McKinsey Cost Curve for Carbon Dioxide Abatement Options, US



McKinsey Cost Curve for Carbon Dioxide Abatement Options, India



Optimizing R&D strategies

Table 1. 'Open' and 'closed' styles of energy research

Open styles	Closed styles
Inclusive of actors at various scales and of differing types	*Exclusive* to a few select firms at limited scales
Participatory and open to multiple stakeholders	*Proprietary* and focused on limiting access
Cooperative and encouraging of information sharing	*Competitive* and encouraging of information hoarding
Decentralized and conducive to diversity and experimentation	*Centralized* and predicated on consolidation and control
Flexible and autonomous in letting researchers refine and adapt on their own	*Rigid* in setting strict goals, methods, materials and/or targets
Holistic in valuing technical and social considerations	*Narrow* in focusing predominantly on technical development

- **This notion of "research style" was then applied to wind energy research in Denmark and the USA, ethanol research in Brazil and France, and hydrogen fuel cell research in Norway and China**

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Table 2. Summary of American, Danish, Brazilian, French, Chinese and Norwegian styles of energy research

	Primary actors	Type of research style	Description	Result
American style of wind energy research	US Department of Energy, US National Aeronautics and Space Administration, large aerospace companies	Closed	Focused on large-scale wind turbines for use in centralized wind farms owned by electric utilities and prioritized hierarchical management and aerospace concepts	Spent approximately $1.1 billion to produce wind turbines that failed in large numbers
Danish style of wind energy research	Municipal cooperatives and individuals, Organization for Information about Atomic Power, Danish Energy Authority, Risà National Laboratory, Association of Danish Wind Power Owners, Association of Danish Wind Mill Manufacturers	Open	Focused on small-scale wind turbines for use in decentralized *kommunes* and prioritized cooperative management and practical concepts	Spent approximately $100 million to produce highly successful wind turbines and establish Denmark as the world's leading wind energy manufacturer
Brazilian style of ethanol research	National Proálcool Program, Aeronautical Technological Center, sugarcane producers, sugarcane distillers, gasoline service stations, automobile companies	Open	Focused on early experimentation with different feedstocks, a gradual scaling up of the research process, collaboration with a diverse array of stakeholders, and directed research to overcome technical and social barriers	Utilized a petrol tax to fund a National Ethanol Program that now produces 16 billion litres of ethanol per year and has made Brazil the largest manufacturer and exporter in the world as well as the country with the largest number of ethanol fueled vehicles that is no longer reliant on subsidies

	Primary actors	Type of research style	Description	Result
French style of ethanol research	French Agency for Environmental and Energy Management (ADEME), Agriculture for Chemicals and Energy (AGRICE)	Closed	Focused on the direct use of sugar beet and wheat waste to produce fuel and intensified research efforts but did not involve major automobile manufacturers or attempt to overcome problems associated with distribution and use	Spent $97 million of government funds to create a program that produces 900 million litres of ethanol per year but is completely dependent on government subsidies, is being rejected by drivers, and will be cancelled by 2012
Chinese style of hydrogen fuel cell research	Dalian Institute of Chemical Physics, Ministry of Science and Technology, Chinese Academy of Sciences, automobile manufacturers, universities, research institutes	Open	Focused on early experimentation with different fuel sources, manufacturing processes and applications for hydrogen fuel cells, gradually scaled up research activities aimed at multiple points of the supply chain with many demonstration projects and forged collaborations with non-governmental groups, universities and industry	Spent $4 million of government revenue per year (at peak) to produce one-quarter of all research patents and the largest manufacturing centre for fuel cells and a growing industry with 60 separate institutions and 350 researchers
Norwegian style of hydrogen fuel cell research	Skandinavias Største Uavhengige Forskningsorganisasjon (SINTEF), Science and Technical Research of Norway (NTNF), Norsk Hydro, Statoil, Statkraft, Elkem	Closed	Focused exclusively on the use of natural gas as a feed stock, did not prioritize demonstration projects, emphasized proprietary control over research results, discouraged information sharing and collaboration	Spent $7 million of government revenue (at peak) to fund three largely redundant research projects that ended up producing little results and have been permanently cancelled

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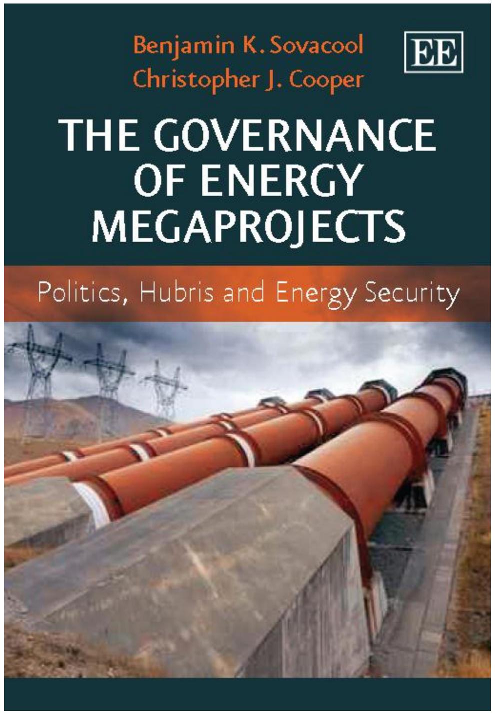

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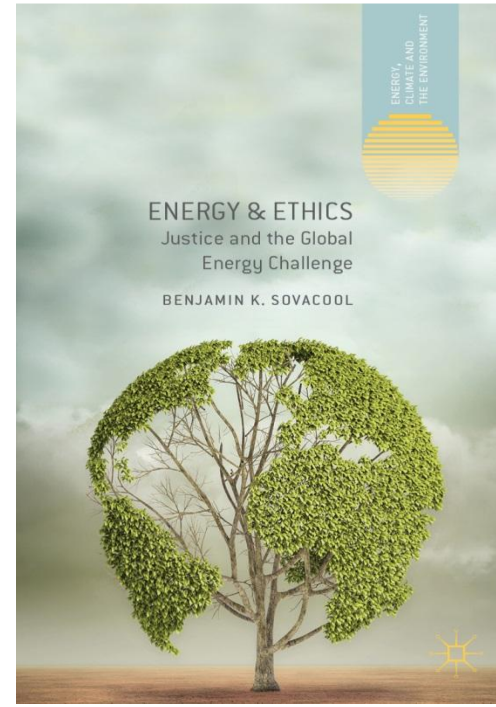

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