NUCLEAR POWER TODAY

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GOALS

- To Understand the Situation and Prospects of the Nuclear Power Enterprise Within the Overall Energy Context
  - Domestically
  - Internationally

NUCLEAR POWER TECHNOLOGIES

GOALS OF NUCLEAR POWER DISCUSSION: To Answer the Following Questions

- Who used nuclear power today?
  Answer: Most industrialized countries.
- Who is likely to use nuclear power in the future?
  Answer: East Asian and developing countries, countries wanting energy supply diversity.
- What are the important nuclear power technologies
  - Today? Answer: LWRs – pressurized and boiling water reactors.
  - Future? Answer: Maybe LWRs near term, gas-cooled reactors medium term, breeder reactors long term.
- How could nuclear power relieve global warming?
  Answer: Most likely with large-scale, high-temperature breeder reactors.
- What are the future prospects for nuclear power?
  Answer: That depends upon how concerned people are about the problems of other energy technologies.

TYPES OF STEAM-ELECTRIC GENERATING PLANTS

Fossil fuel, Nuclear BWR, Nuclear PWR, Nuclear LMFBR

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TYPES OF STEAM-ELECTRIC GENERATING PLANTS

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Fossil fuel, Nuclear BWR, Nuclear PWR, Nuclear LMFBR

NUCLEAR POWER STATUS WORLDWIDE

- About 440 Reactors Operating
- Source of 17% of Worldwide Electricity
- Source of 25% of Electricity in Industrial Countries
- Source of 20% of United States Electricity (103 Reactors)
- Effective New Plant Moratoria in Most Industrialized Countries
- Japan, France Ordering a New Plant Every Few Years
- China, Korea, Taiwan Have Been Ordering Frequently
  Some annual electricity demand growth rates near 10% until recently
- Finland Is Ordering a New Plant

SUMMARY OF TYPES OF POWER REACTORS USED WORLDWIDE

Type	Coolant	Moderator	Coolant Temperature (C)	Deployment	Current Population
Pressurized Water (PWR)	Light Water	Light Water	300	Most nuclear countries	236
Boiling Water (BWR)	Light Water	Light Water	300	Most nuclear countries	88
RBMK	Light Water	Graphite	300	Former USSR*	16
Pressurized Heavy Water (PHWR)	Heavy Water	Heavy Water	300	Canada, Korea, China, Argentina, India, Pakistan	31
Gas-Cooled (GCR)	Carbon Dioxide, Helium	Graphite	600	UK, Russia	38
Liquid Metal-Cooled (LMFBR)	Sodium, Lead, Lead-Bismuth	None	600	France, UK, Japan, Russia; former USSR, China and India	7

*Union of Soviet Socialists Republics

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Growth of nuclear power in France, 1970 to 1994.

NUCLEAR POWER STATUS AROUND THE WORLD

Table removed for copyright reasons.

Reactors in operation and under construction, by country - 2001.

RECENT ELECTRIC INDUSTRY TRENDS IN UNITED STATES

- Preparation for Competition
- Power upgrades
- Uncertainty in deregulation pace
- Growth of Combined Cycle Gas Turbine Units
- Merchant plant sector has been growing
- Nuclear Power Plant Set Has Stabilized at 103
  - 2/3 PWR, 1/3 BWR
  - Six units were shut-down
  - No units are being built
  - A few restarts are being considered
- Nuclear Workforce is Old

SOME INTEREST IN NEW NUCLEAR PLANTS

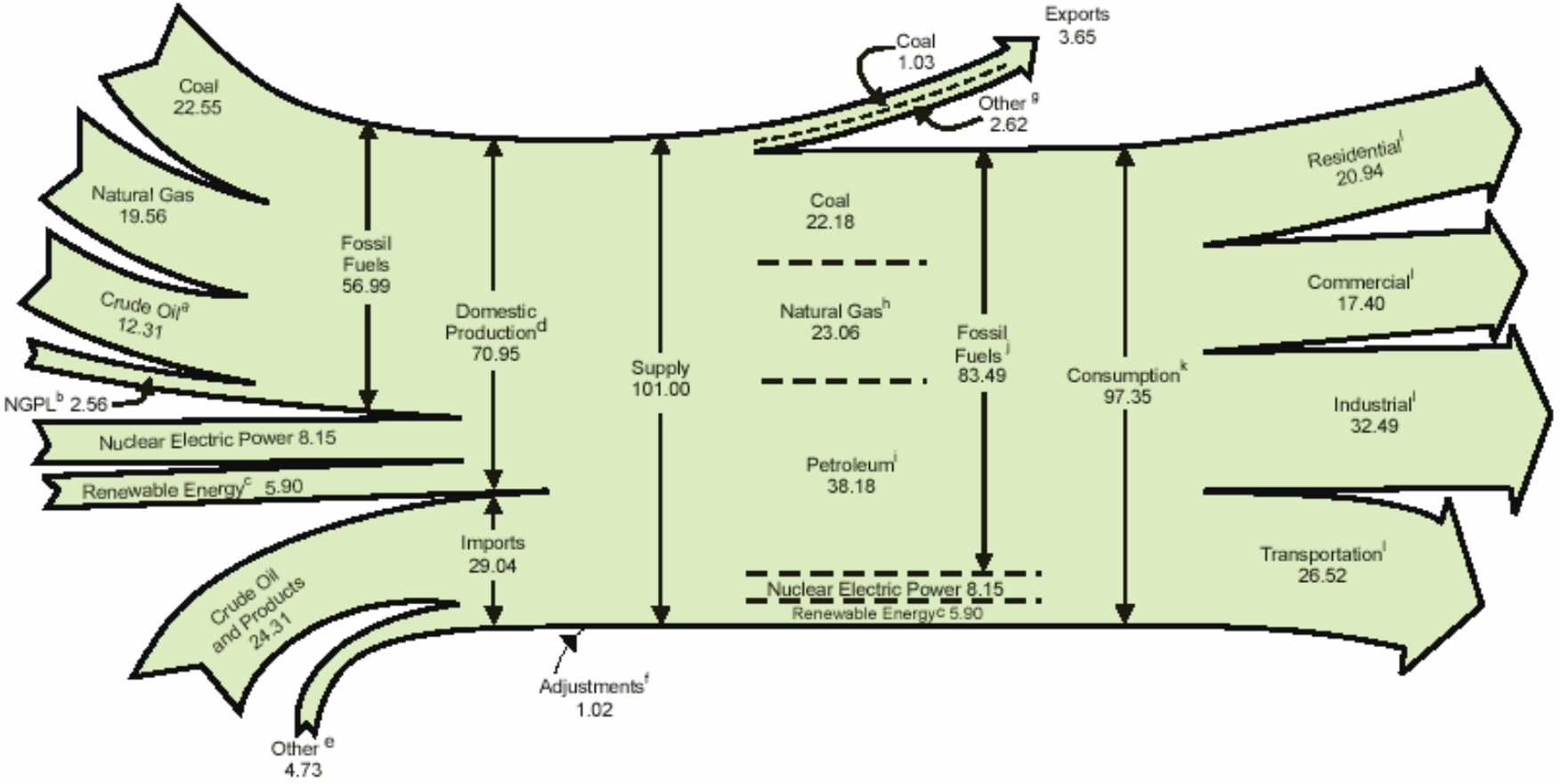
- Nuclear Power Reduces Global Warming, Regional Air Pollution
- DOE/Utility Combined Operating License (COL) Initiative, New Site Licensing
  - Group 1: Constellation, Entergy, Exelon, Southern, EDF International, Westinghouse
  - Group 2: Dominion, GE, Hitachi, Bechtel
- BNFL Participation in South African Pebble-Bed, Gas-Cooled Reactor (formerly Exelon, too)
- PCAST Report (to President) Favorable to Nuclear Projects
- USDOE's Generation-IV Reactor Program (with Nine Other Countries)
- High Capital Costs Are Still a Problem

GENERATION-IV REACTOR DEVELOPMENT PROGRAM

TEN COUNTRIES PARTICIPATING

- Positive Reactor Products
  - Electricity
  - High Temperature Heat
  - Hydrogen
  - Water
  - Fertilizer
- Concepts
  - Super Critical Water Reactor
  - Very High Temperature (Gas-Cooled) Reactor
  - Sodium-Cooled Fast Breeder Reactor
  - Lead-Bismuth-Cooled Fast Breeder Reactor
  - Gas-Cooled Fast Breeder Reactor
  - Molten Salt Reactor

ENERGY FLOW, 2002 (Quadrillion Btu)



[a] Includes lease condensate.

[b] Natural gas plant liquids.

[c] Conventional hydroelectric power, wood, waste, ethanol blended into motor gasoline, geothermal, solar, and wind.

[d] Includes -0.09 quadrillion Btu hydroelectric pumped storage.

[e] Natural gas, coal, coal coke, and electricity.

[f] Stock changes, losses, gains, miscellaneous blending components, and unaccounted-for supply.

[g] Crude oil, petroleum products, natural gas, electricity, and coal coke.

[h] Includes supplemental gaseous fuels.

[i] Petroleum products, including natural gas plant liquids.

[j] Includes 0.06 quadrillion Btu of coal coke net imports.

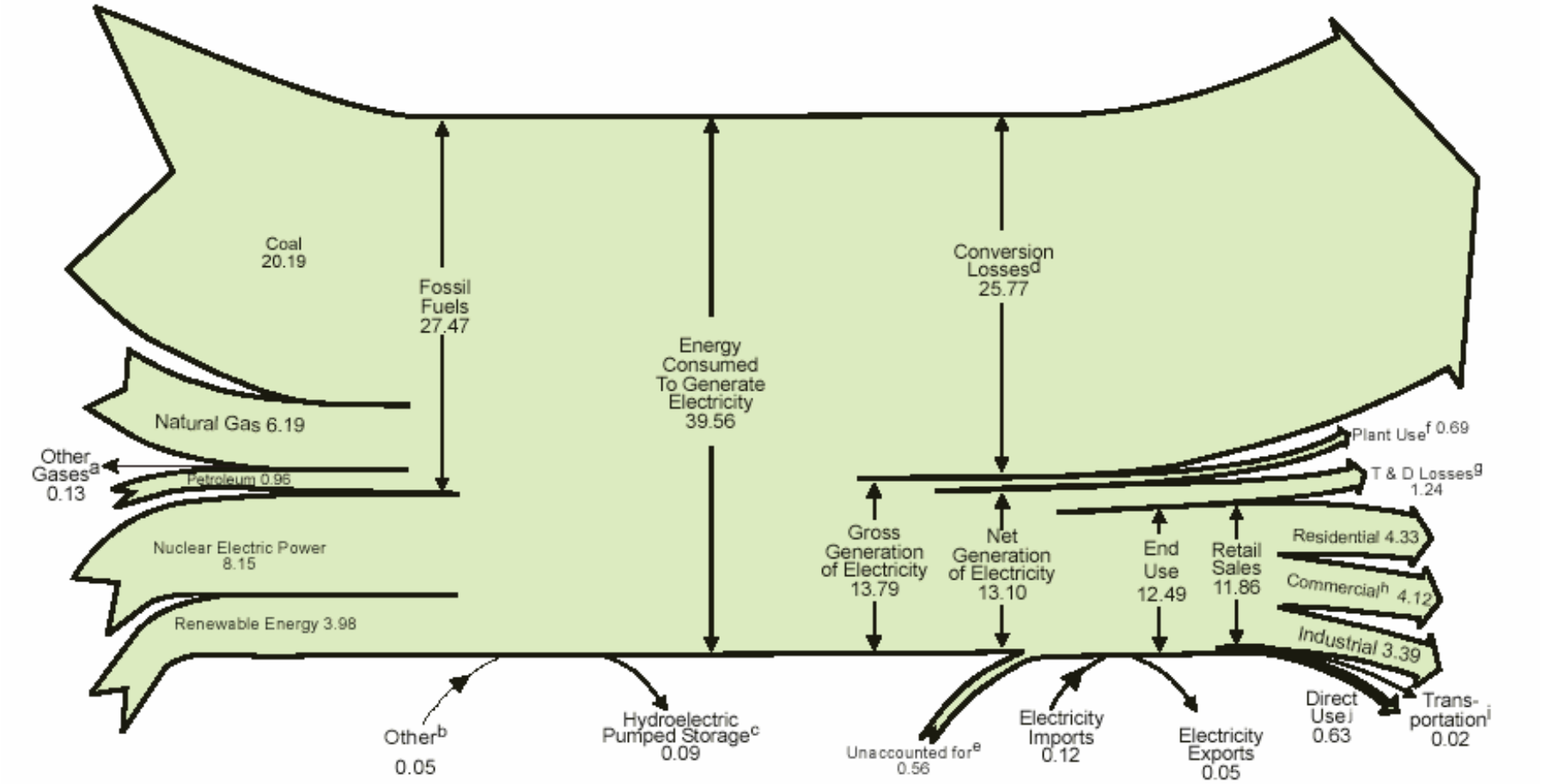
[k] Includes, in quadrillion Btu, -0.09 hydroelectric pumped storage; -0.17 ethanol blended into motor gasoline, which is accounted for in both fossil fuels and renewable energy but counted only once in total consumption; and 0.08 electricity net imports.

[l] Primary consumption, electricity retail sales, and electrical system energy losses, which are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See note at end of Section 2.

Notes: • Data are preliminary. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 1.1, 1.2, 1.3, 1.4, and 2.1a.

ELECTRICITY FLOW, 2002 (Quadrillion Btu)



[a] Blast furnace gas, propane gas, and other manufactured waste gases derived from fossil fuels.

[b] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

[c] Pumped storage facility production minus energy used for pumping.

[d] Approximately two-thirds of all energy used to generate electricity. See note at end of Section 2.

[e] Data collection frame differences and non-sampling error.

[f] Electric energy used in the operation of power plants, estimated as 5 percent of gross generation. See note at end of Section 2.

[g] Transmission and distribution losses, estimated as 9 percent of gross generation. See note at end of Section 2.

[h] Commercial retail sales plus approximately 95 percent of "Other" retail sales from Table 8.5.

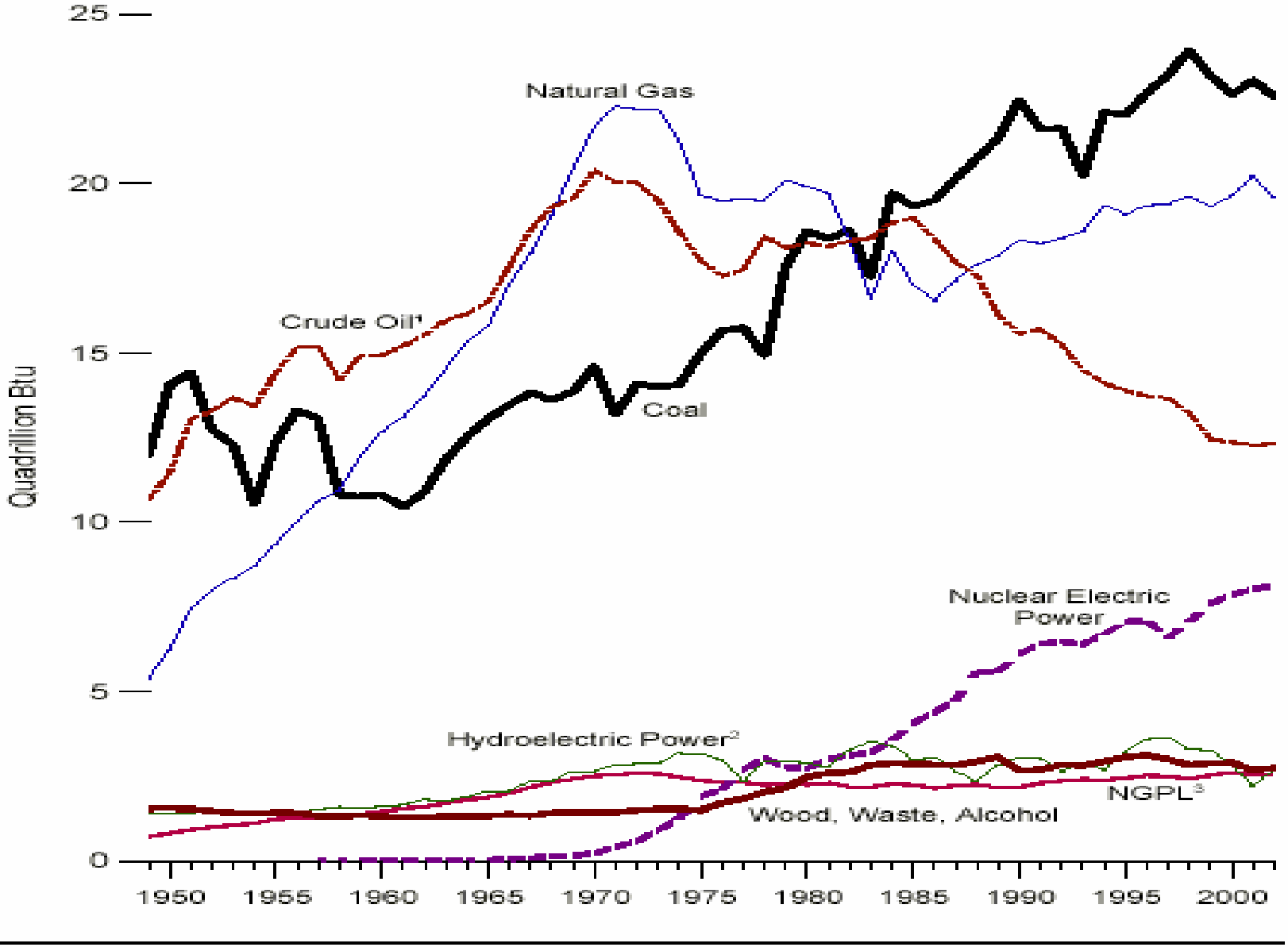
[i] Approximately 5 percent of "Other" retail sales from Table 8.5.

[j] Commercial and industrial facility use of onsite net electricity generation; and electricity sales among adjacent or co-located facilities for which revenue information is not available.

Note: Totals may not equal sum of components due to independent rounding.

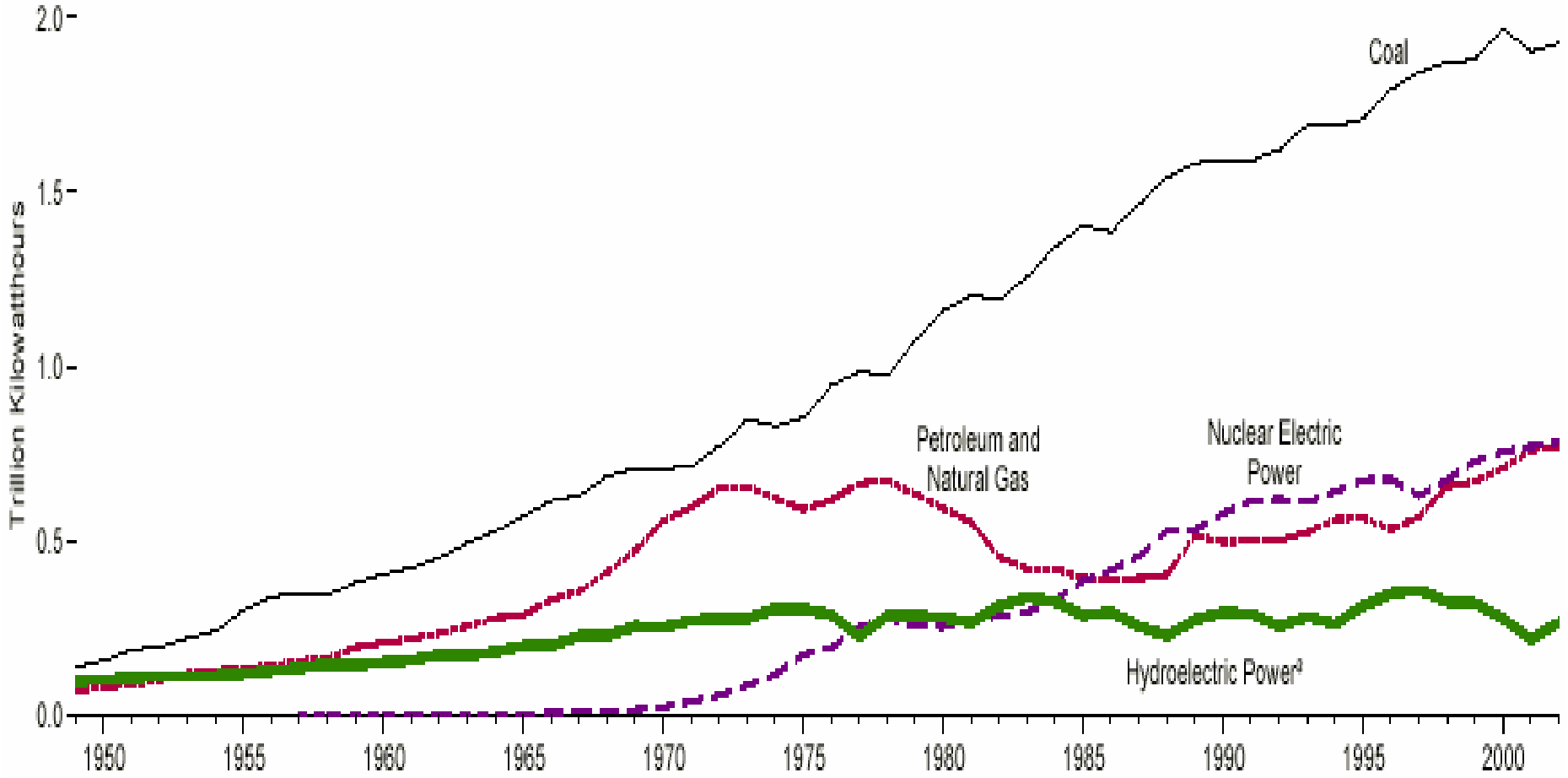
Sources: Tables 2.2a, 8.1, 8.5, and A6.

ENERGY PRODUCTION BY SOURCE



(s)=Less than 0.5 quadrillion Btu.
Note: Because vertical scales differ, graphs should not be compared.
Source: Table 1.2.

ELECTRICITY NET GENERATION

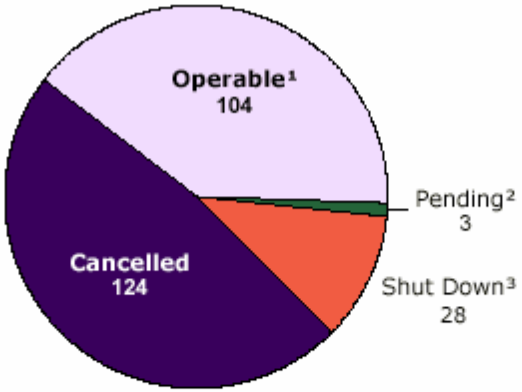


[1] Combined-heat-and-power.
[2] Petroleum, other gases, wood, waste, geothermal, solar, wind, and other.
[3] Conventional hydroelectric power and pumped-storage.

Note: Because vertical scales differ, graphs should not be compared.
Sources: Tables 8.2a, 8.2b, and 8.2c.

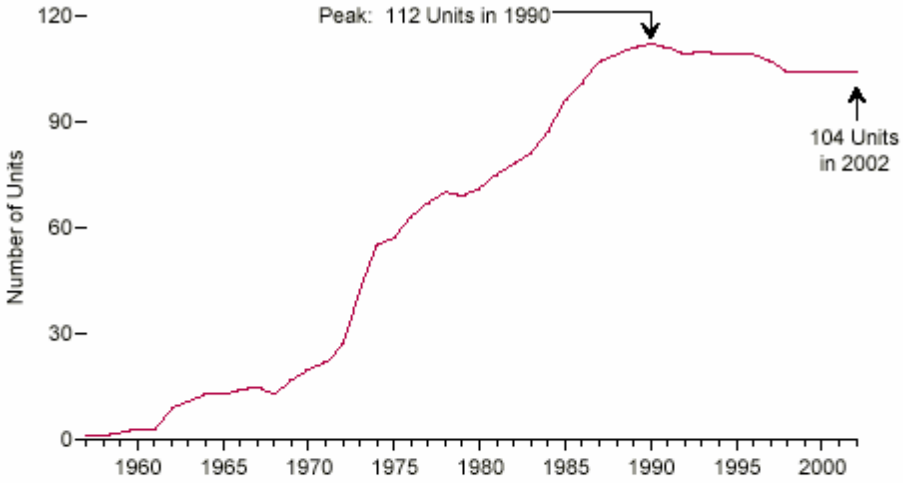
NUCLEAR GENERATING UNITS

Status of All Ordered Units, 1953-2002

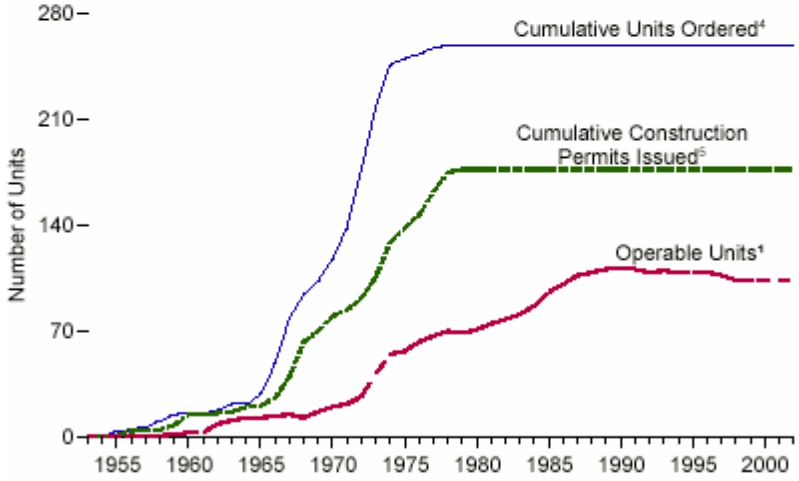


Total Units Ordered: 259

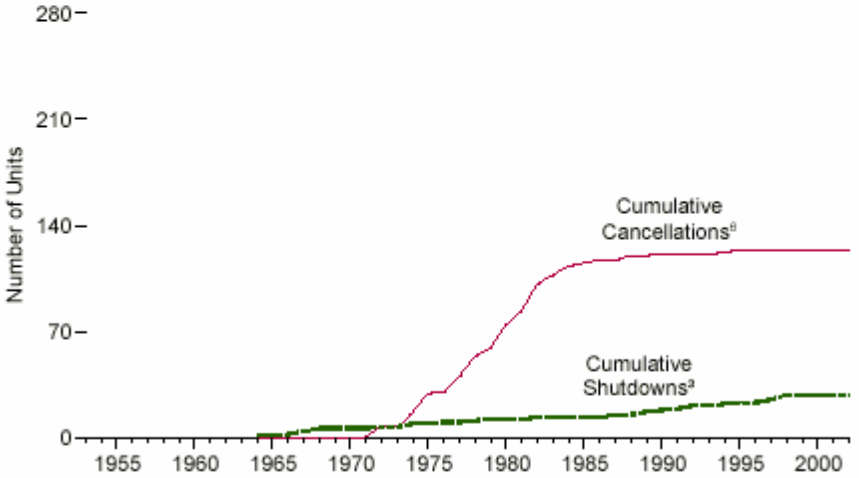
Operable Units,[1] 1957-2002



Orders, Permits, and Operable Units, 1953-2002



Cancellations and Shutdowns, 1953-2002



[1] Issuance by a regulatory authority of full-power operating license, or equivalent permission to operate.
[2] Ordered but not completed or cancelled.
[3] Ceased operation permanently.
[4] Placement of an order by a utility for a nuclear steam supply system.
[5] Issuance by a regulatory authority of a permit, or equivalent permission, to begin construction.
[6] Cancellation of ordered units.
Note: Data are at end of year.
Source: Table 9.1.

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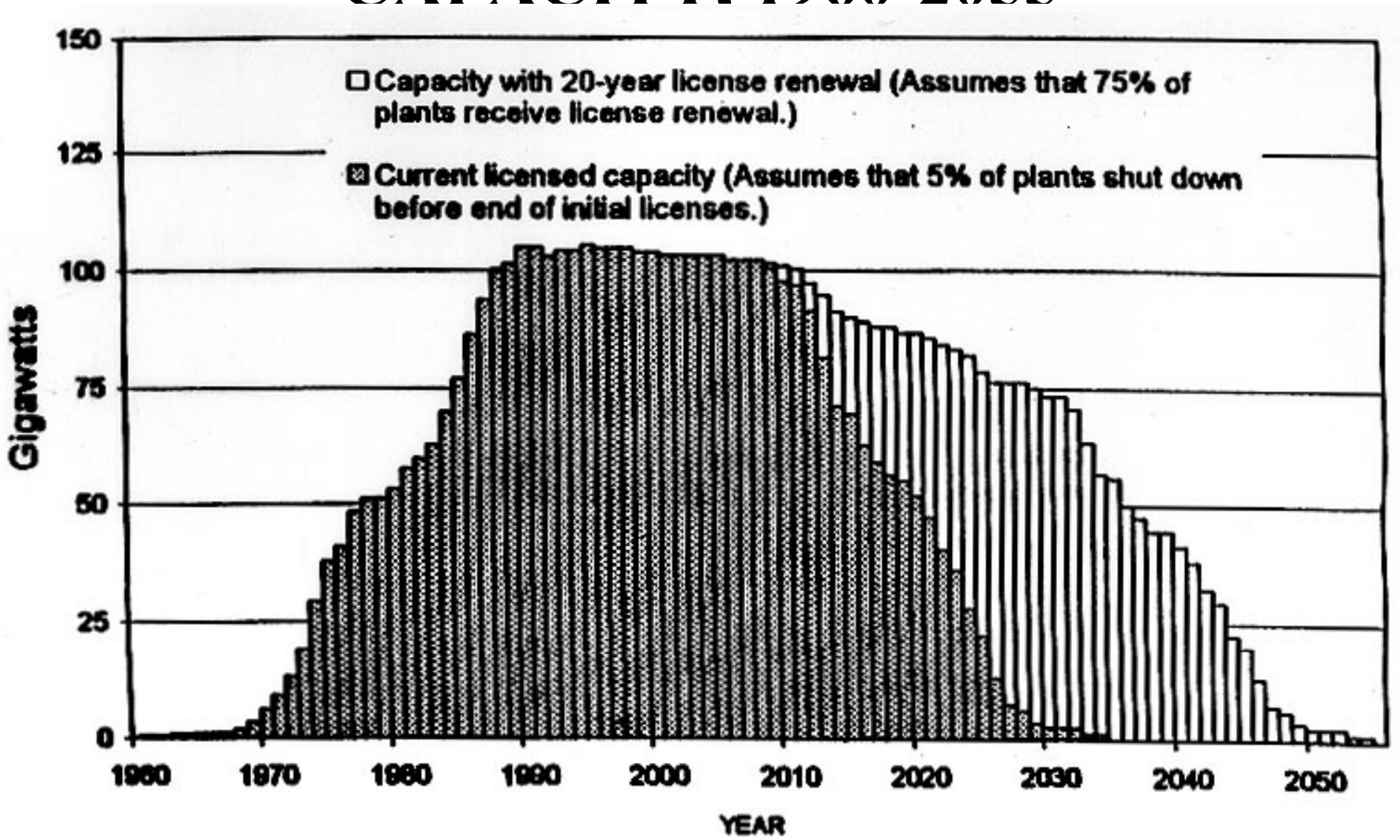
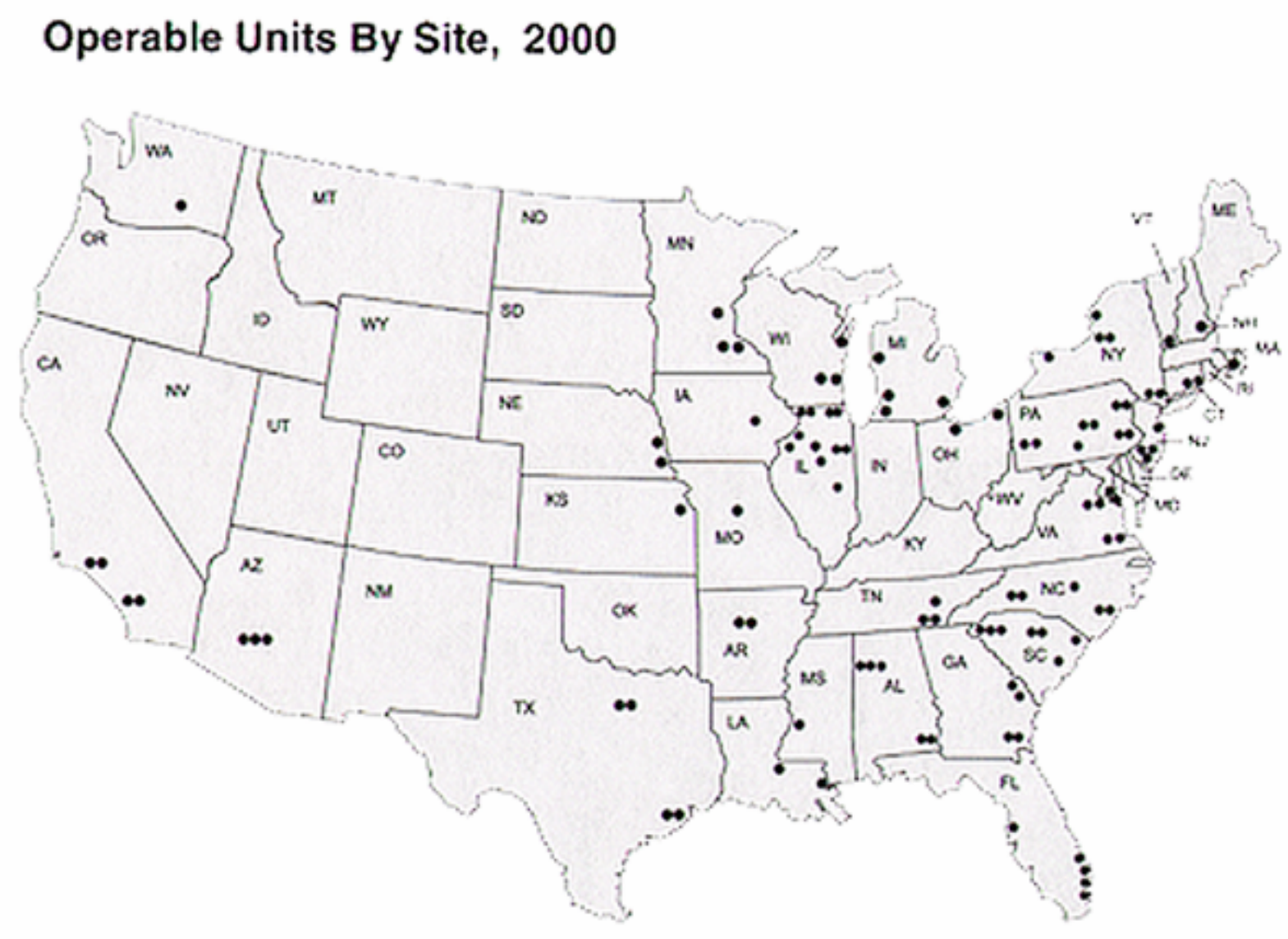
HISTORICAL AND PROJECTED US NUCLEAR ELECTRIC GENERATION CAPACITY. 1960-2055



NUCLEAR GENERATING UNITS



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INTERNATIONAL TRENDS

- Deregulation originated in the United Kingdom, went well until recently; now British Energy is near bankruptcy

- Deregulation is also being tried in United States, Canada, Chile, Japan, South Korea, Australia, and European Community

- Consolidation among nuclear equipment vendors is occurring: Framatome ANP, British Nuclear Fuels Ltd, General Electric/Toshiba, Hitachi, Mitsubishi Heavy Industries

REGIONAL FACTORS

EUROPE

- Electricite de France is a big exporter and owner, preparing for competition
- Nuclear power shutdowns have been voted in Sweden, Germany and Belgium
- Fifth Finnish nuclear unit order is proceeding

AFRICA

- South Africa developing the pebble bed modular reactor (PBMR)

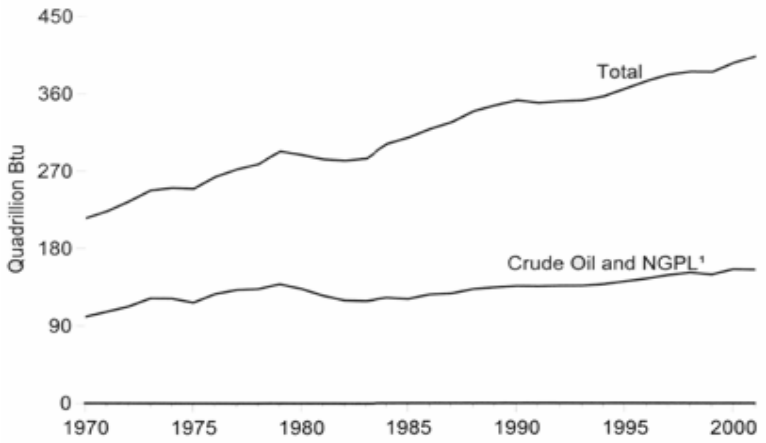
REGIONAL FACTORS, continued

ASIA

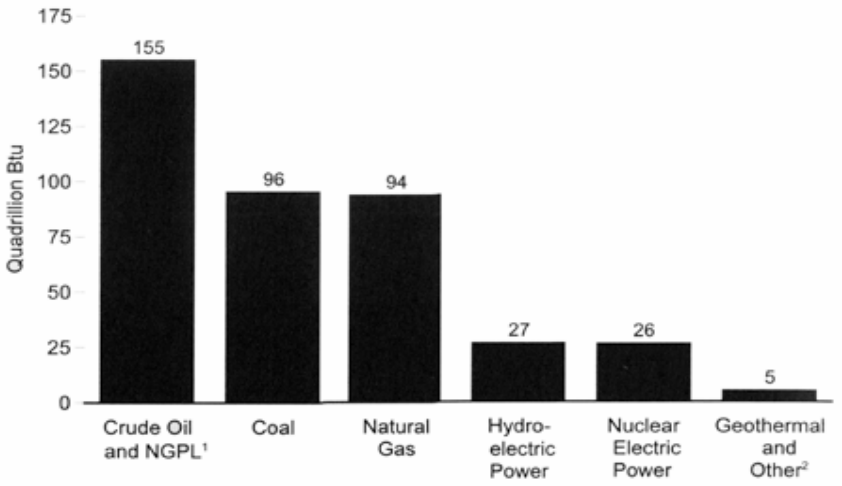
- China is accelerating its nuclear power program as an alternative to coal-based electricity, two units in pipeline now
- Japan has three units in pipeline; cover-up scandals settling down; all 15 units of TEPCO were off-line during March ’03
- South Korea had privatized KEPCO, is planning a new series of LWRs, has six units in pipeline
- Taiwan is completing two BWRs (Units 7 & 8); nothing is planned beyond them

WORLD PRIMARY ENERGY PRODUCTION BY SOURCE

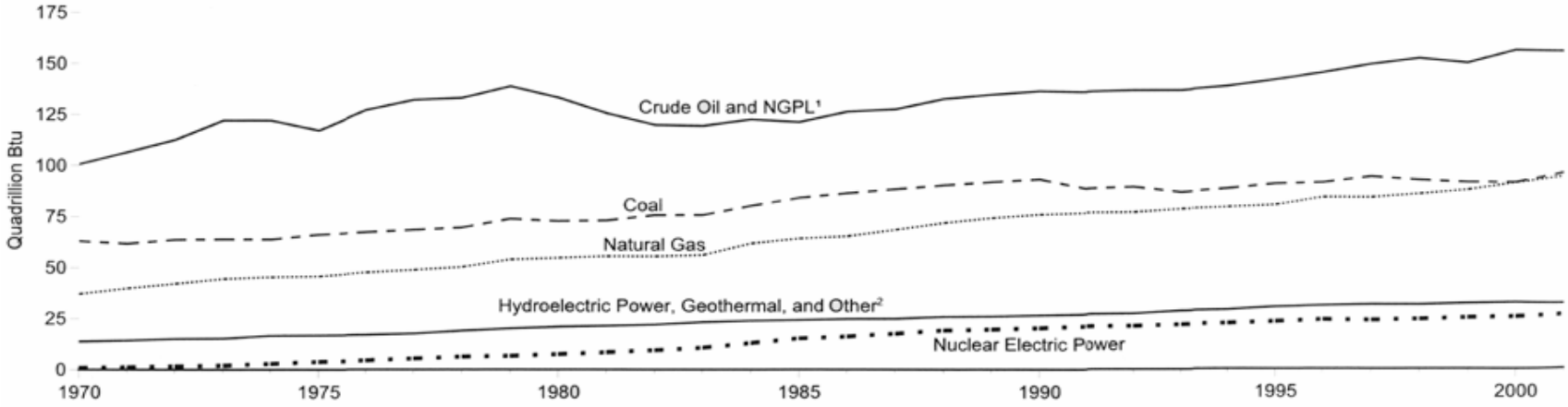
Total and Crude Oil and NGPL[1], 1970-2001



By Source, 2001



By Source, 1970-2001



[1]Natural gas plant liquids.
[2]Net electricity generation from wood, waste, solar, and wind. Data for the United States also include other renewable energy.

Notes: • Crude oil includes lease condensate. • Because vertical scales differ, graphs should not be compared.
Source: Table 11.1.

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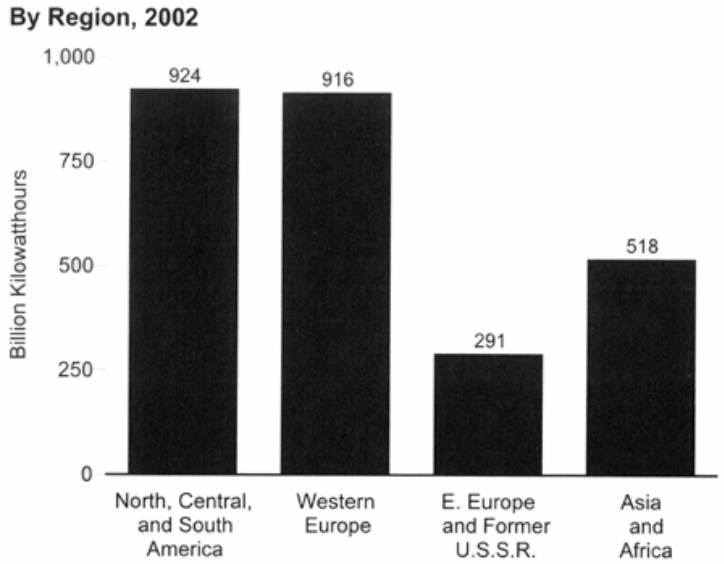
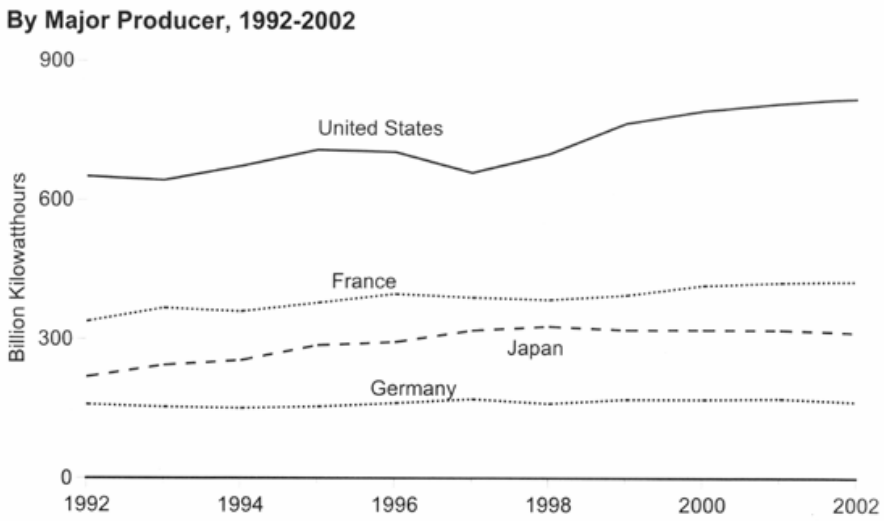
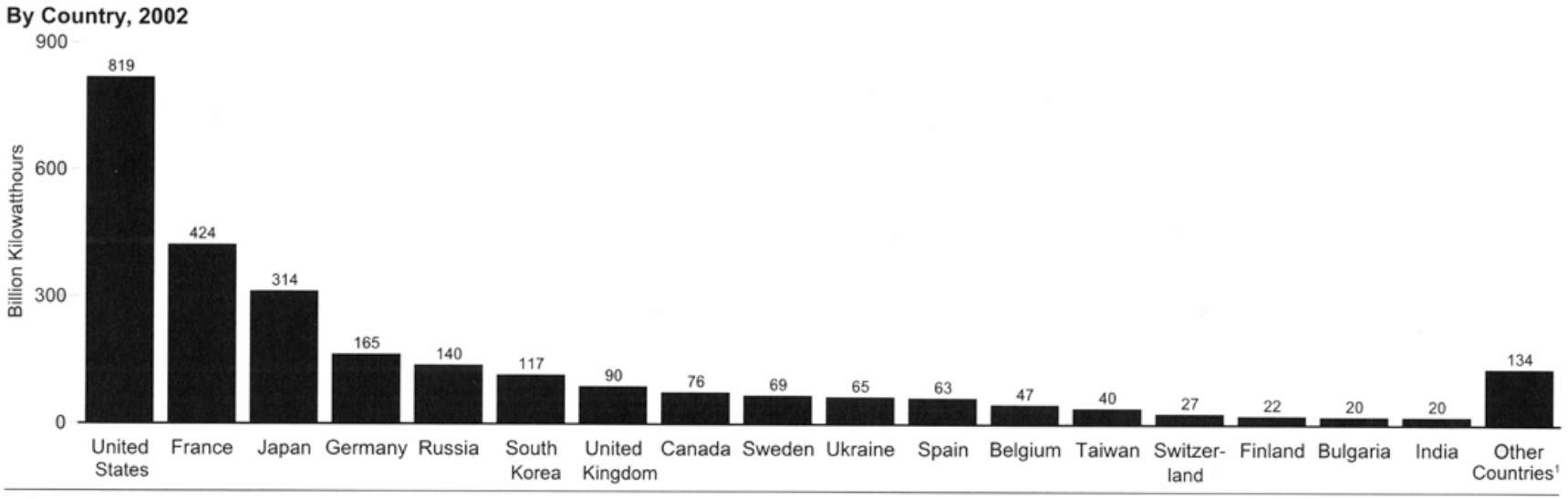
WORLD NUCLEAR ELECTRICITY GROSS GENERATION



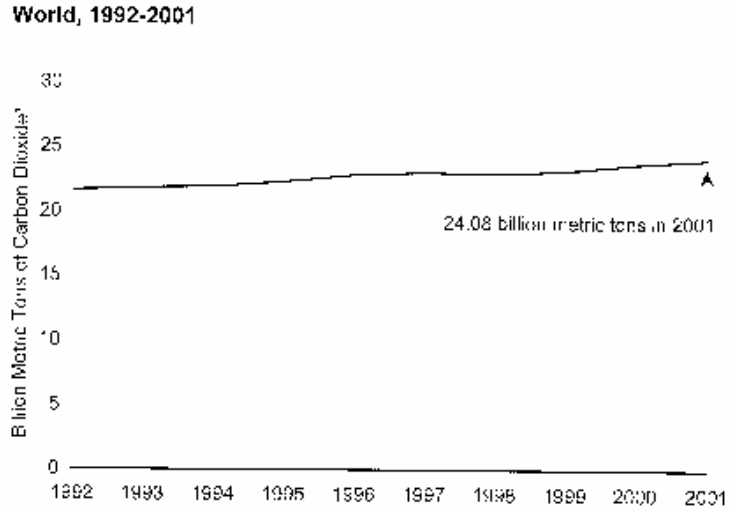


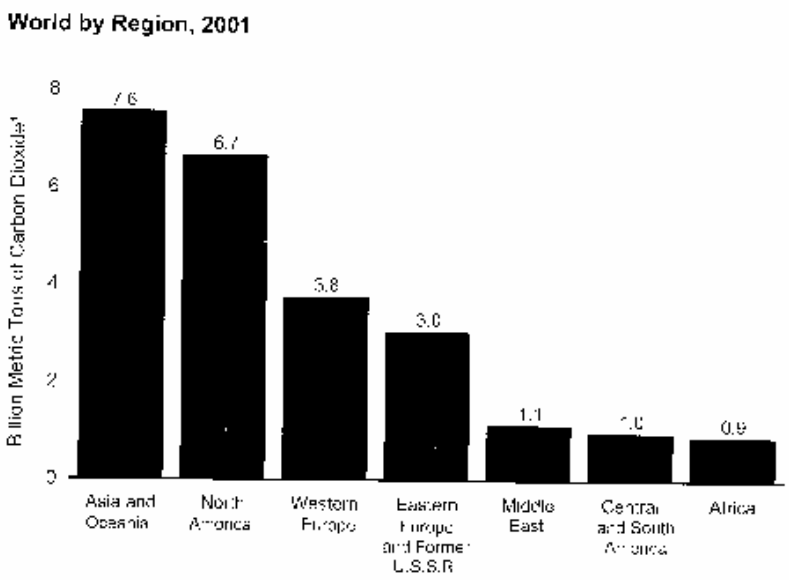


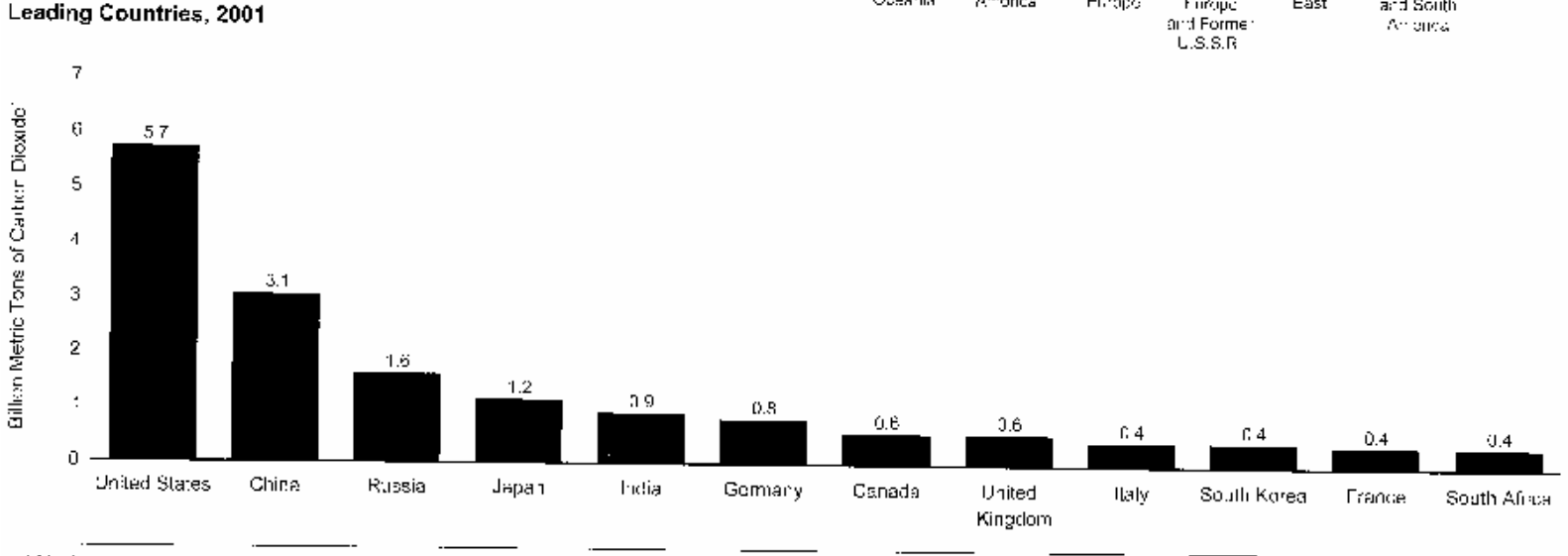
[1] Argentina, Armenia, Brazil, China, Czech Republic, Hungary, Lithuania, Mexico, Netherlands, Pakistan, Romania, Slovakia, Slovenia, and South Africa.

Note: Because vertical scales differ, graphs should not be compared.
Source: Table 11.18.

WORLD CARBON DIOXIDE EMISSIONS FROM ENERGY CONSUMPTION







* Metric tons of carbon dioxide can be converted to metric tons of carbon equivalent by multiplying by 12/44.

Notes: Data include emissions from natural gas flaring. • Because vertical scales differ, graphs should not be compared.

Source: Table 11.19.

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PLAUSIBLE TRENDS IN REACTOR TECHNOLOGY EVOLUTION

CURRENT/SHORT TERM

Light Water Reactors (LWRs)

- Pressurized Water Reactor (PWR)
- Boiling Water Reactor (BWR)
- Pressurized Heavy Water Reactor (CANDU)

INTERMEDIATE TERM (>20 years)

Brayton Cycle Gas (He) Cooled Reactor (GCR-GT)

LONG TERM (>50 years)

Fast Breeder ($^{238}U \varnothing ^{239}Pu$-based)

Thermal Breeder ($^{232}Th \varnothing ^{233}U$-based)

MHTGR SIDE-BY-SIDE ARRANGEMENT WITH PRISMATIC FUEL

Diagram removed for copyright reasons.

FACTORS LIKELY TO AFFECT FUTURE USE OF NUCLEAR POWER

Operational Safety Record

Utility, Critical Elite, Public, Investor Attitudes

End of Cold War

Degree of Nuclear Weapons Proliferation

Nuclear Waste Disposal Success

Global Warming and Air Pollution Worries