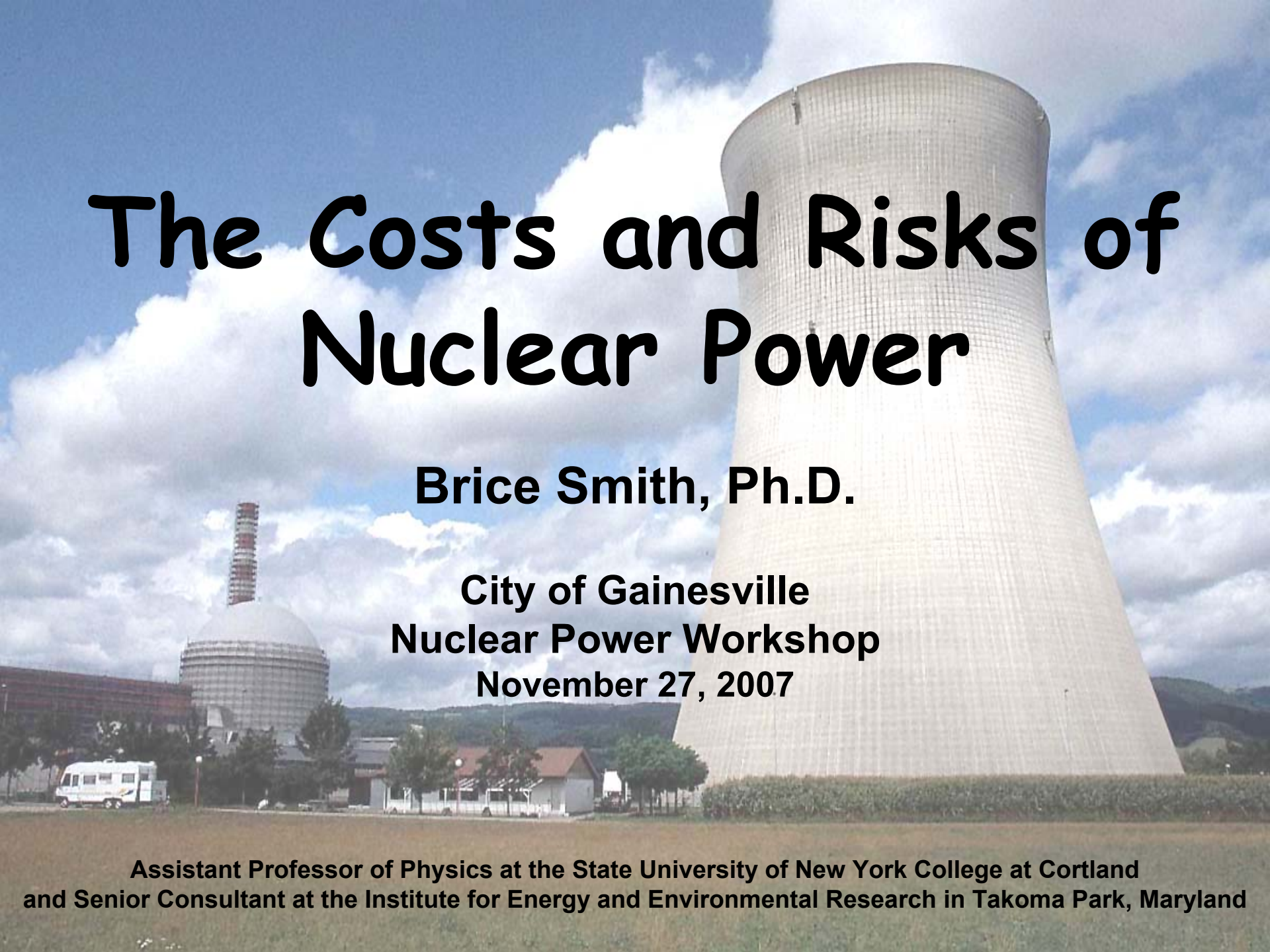


The Costs and Risks of Nuclear Power

Brice Smith, Ph.D.

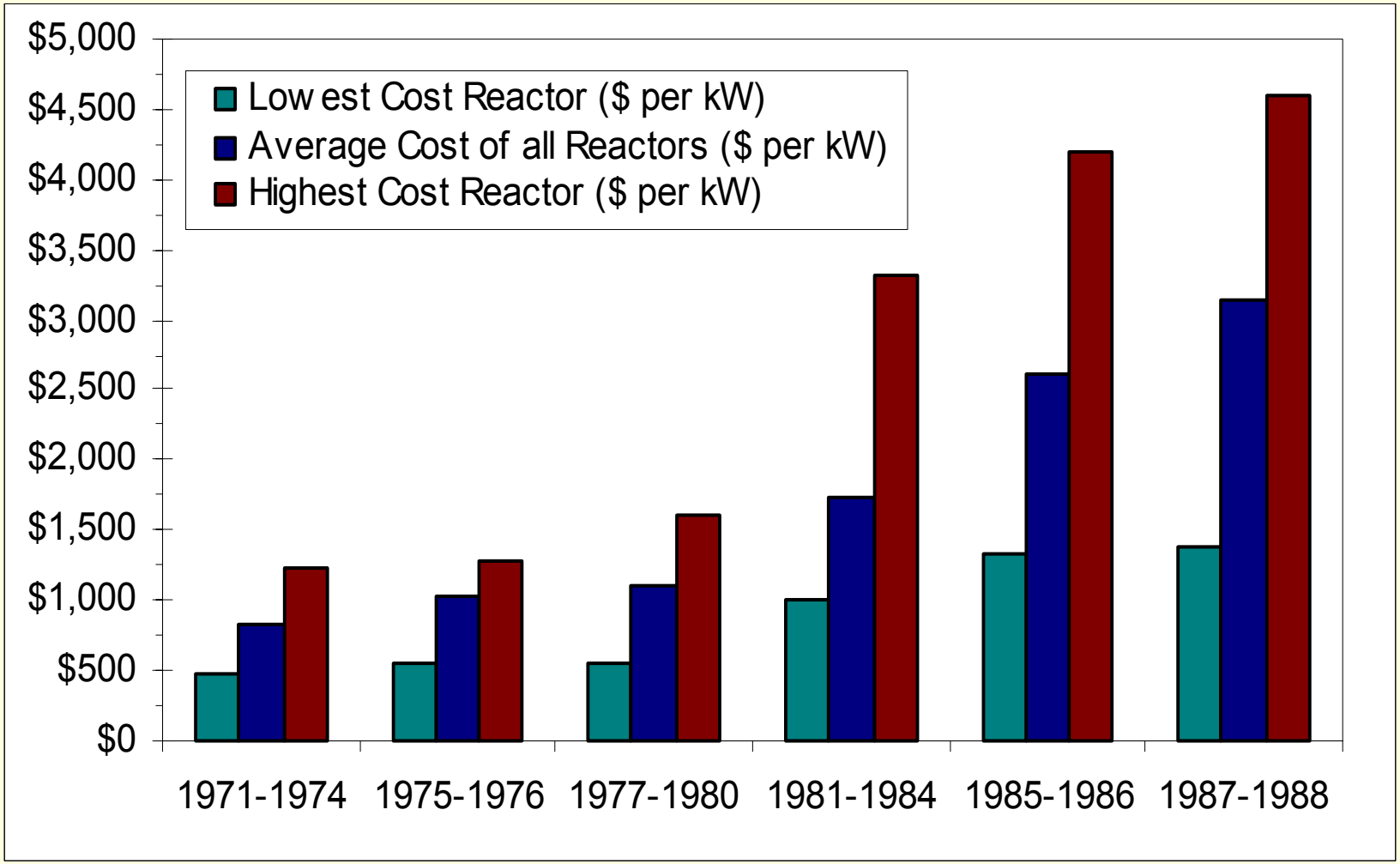
City of Gainesville
Nuclear Power Workshop
November 27, 2007

Assistant Professor of Physics at the State University of New York College at Cortland
and Senior Consultant at the Institute for Energy and Environmental Research in Takoma Park, Maryland

Asking the Right Questions

- How much will nuclear power cost compared to other ways to lower carbon dioxide emissions from the electricity sector?
- What are the risks associated with serious accidents at a nuclear power plant approximately 60 miles from Gainesville?
- What are the concerns raised by the nuclear waste that would be generated?
- What are some of the possible alternatives?

The Economics of Nuclear Power



The Economics of Nuclear Power

- The largest bond default in utility history, which was a major element in the collapse of Chemical Bank, occurred in the early 1980s because of unrecoverable investments in two canceled nuclear power reactors being constructed by Washington Public Power Supply System in Washington State.
- **"Because the cost of power from the first of the next generation of new nuclear power plants would likely be significantly above prevailing market rates, we would expect that the plant operators would default on the borrowing that financed its capital costs."**

  - U.S. Congressional Budget Office, May 2003

The Economics of Nuclear Power

- Between 1972 and 1984, more than $20 billion was spent on 115 nuclear plants that were later canceled.
- By 1992, a total of 121 reactors had been canceled, not counting those that had been ordered but were canceled before much money had been spent.
- By the early 1980s, the choice to continue pursuing nuclear construction was recognized as an important factor in the downgrading of utility credit ratings by Standard & Poor's.
- No new nuclear plants have been ordered in the U.S. since 1978, and the two orders that were placed in 1978 were subsequently canceled. In fact, it has been ten years since the last new reactor was brought online in the United States

The Economics of Nuclear Power

"The failure of the U.S. nuclear power program ranks as the largest managerial disaster in business history, a disaster on a monumental scale. The utility industry has already invested $125 billion in nuclear power, with an additional $140 billion to come before the decade is out, and only the blind, or the biased, can now think that most of the money was well spent. It is a defeat for the U.S. consumer and for the competitiveness of U.S. industry, for the utilities that undertook the program and for the private enterprise system that made it possible."

- James Cook in *Forbes Magazine* cover story (1985)

The Economics of Nuclear Power

Year in Which Construction Began	Percentage of Plant Completed When Estimate Was Made	Percent by Which the Utility Underestimated the Final Construction Cost	Percent by Which the Utility Underestimated the Total Construction Time
1966-1969	0%	63%	47%
	75%	22%	21%
1974-1977	0%	72%	45%
	75%	24%	12%

Megawatts and Mushroom Clouds

- “The development of atomic energy for peaceful purposes and the development of atomic energy for bombs are in much of their course interchangeable and interdependent.”
  - Acheson - Lilienthal Report (1946)

- “No system of safeguards that can be devised will of itself provide an effective guarantee against production of atomic weapons by a nation bent on aggression.”
  - Joint statement of President Harry Truman, Prime Minister Clement Attlee, and Prime Minister William Mackenzie King (November 1945)

Uranium Enrichment Services

"The next decade will see something very unusual in the nuclear fuel cycle: all of the world's commercial enrichment enterprises will be engaged at the same time in re-building and to a lesser extent expanding their industrial capacities."

- Expert Group Report submitted to the Director General of the International Atomic Energy Agency (2005)

<u>Gaseous Diffusion → Gas Centrifuges</u>

France 10,800 MTSWU to 7,500 MTSWU
U.S. 11,300 MTSWU to 6,500 MTSWU (2 plants)

The Lessons of Three Mile Island

- “When playing Russian roulette, the fact that the first shot got off safely is of little comfort for the next.”
  - Richard Feynman discussing the failures that led to the destruction of the Space Shuttle Challenger

- “The abiding lesson that Three Mile Island taught Wall Street was that a group of N.R.C.-licensed reactor operators, as good as any others, could turn a $2 billion asset into a $1 billion cleanup job in about 90 minutes.”
  - Peter Bradford, former commissioner of the U.S. Nuclear Regulatory Commission (2005)

The Lessons of Davis-Besse

- In March 2002, a pineapple sized hole in the reactor vessel caused by corrosion was discovered at Davis-Besse Plant near Toledo, Ohio
- The only material left to contain the superheated cooling water, exerting more than 2,180 pounds per square inch of pressure inside the reactor core, was a stainless steel liner just 0.125 inches thick.

"There was a focus on production, established by management, combined with taking minimum actions to meet regulatory requirements, that resulted in the acceptance of degraded conditions."

- FirstEnergy Nuclear Operating Company, 2002

Probability, Consequences, and Risk

- "No reactor system has ever failed because of a deficiency that could be seen on a designer's flow sheet or an analyst's model. Such deficiencies have been revealed only via operating experiences."

- "There is not now and never will be a "typical" or "average" human being whose performance and reactions to any operating condition, let alone an abnormal operating condition, can be cataloged, qualitatively defined, or quantitatively determined. There are no human robots."

  - Edward Hagen, a development specialist at Oak Ridge National Laboratory and editor of the Control and Instrumentation section of the journal *Nuclear Safety* (1980)

Probability, Consequences, and Risk

"We should remember that risk assessment data can be like the captured spy: if you torture it long enough, it will tell you anything you want to know."

- William Ruckelshaus, the head of the U.S. Environmental Protection Agency under both Presidents Richard Nixon and Ronald Reagan (1984)

The Legacy of Nuclear Waste

"As I reflect on my own involvement in the waste problem, I have these regrets. Most importantly, during my years at ORNL [Oak Ridge National Laboratory] I paid too little attention to the waste problem. Designing and building reactors, not nuclear waste, was what turned me on…. Indeed, as I think about what I would do differently had I to do it over again, it would be to elevate waste disposal to the very top of ORNL's agenda."

- Alvin Weinberg, Director of Oak Ridge National Laboratory from 1955 to 1973 (1994)

"Low-level" Nuclear Waste

- Florida is part of the Southeast Regional Compact along with Alabama, Mississippi, Tennessee, Georgia, and Virginia.
- As of July 1, 2008 the only existing disposal facility for Class B and C low-level waste now open to Florida will close to facilities outside the Atlantic Compact (South Carolina, New Jersey and Connecticut).
- The plans for managing this waste should be carefully explored for the proposed Levy County nuclear plant.

The Legacy of Nuclear Waste

- Half-life of some of the important radionuclides in spent nuclear fuel
  - Plutonium-239 = 24,000 years
  - Tecnitium-99 = 212,000 years
  - Cesium-135 = 2.3 million years
  - Iodine-129 = 15.7 million years
- Earliest known evidence of agriculture and domesticated animals is approximately 12,000 years ago

The Legacy of Nuclear Waste

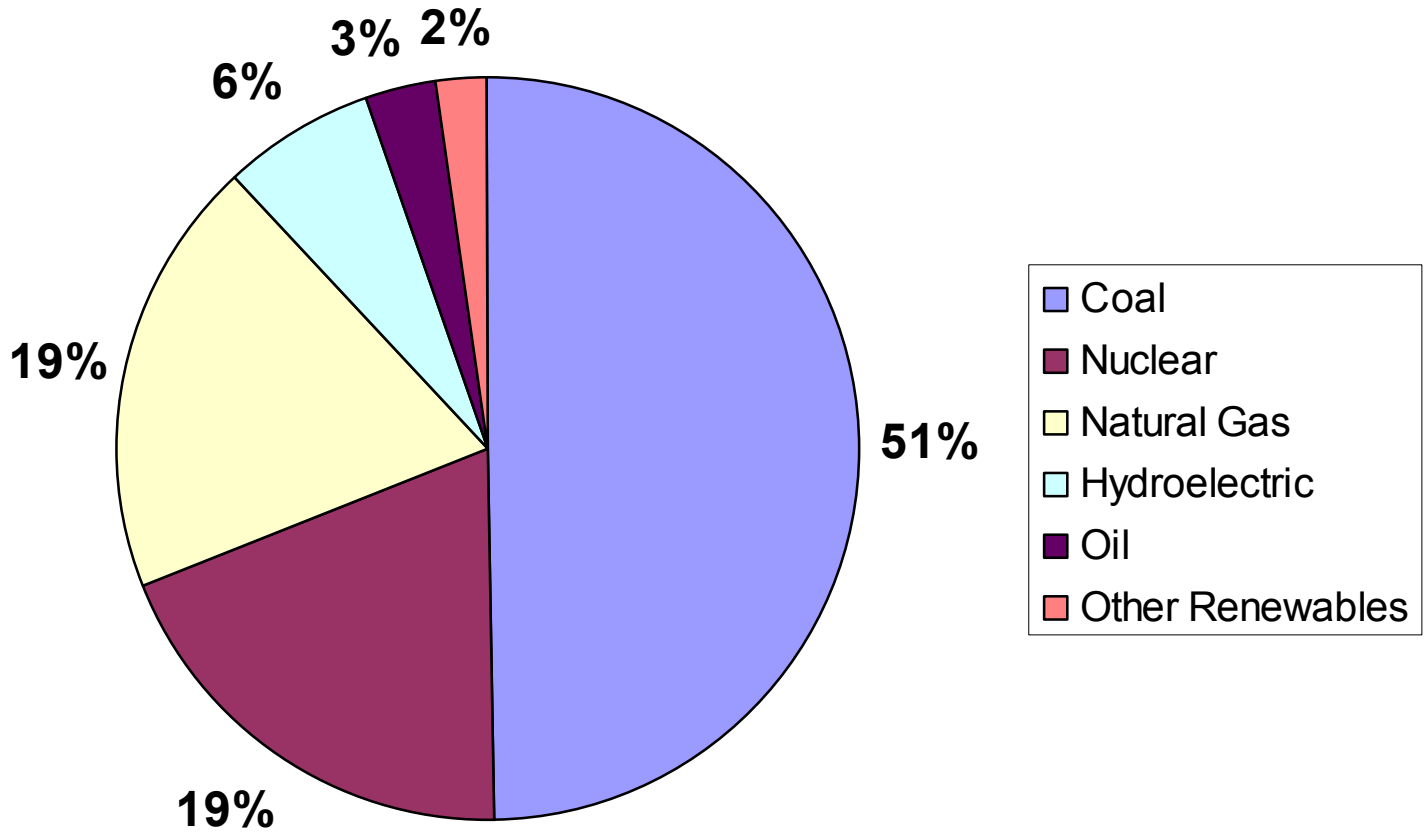
- **Yucca Mountain (Nevada)**
  - Sole site for characterization since 1987.
  - More than $9 billion already spent.
  - As yet no license application has been submitted. In fact, there has not yet been a final radiation standard promulgated for the repository by the Environmental Protection Agency.

- "It is unclear whether Yucca Mountain will ever receive a license from the Nuclear Regulatory Commission. "
  - Ernest Moniz and John Deutch, both former Undersecretaries in the U.S. Department of Energy and co-chairs of the MIT study, *The Future of Nuclear Power* (January 2006)

Reprocessing as Waste Management

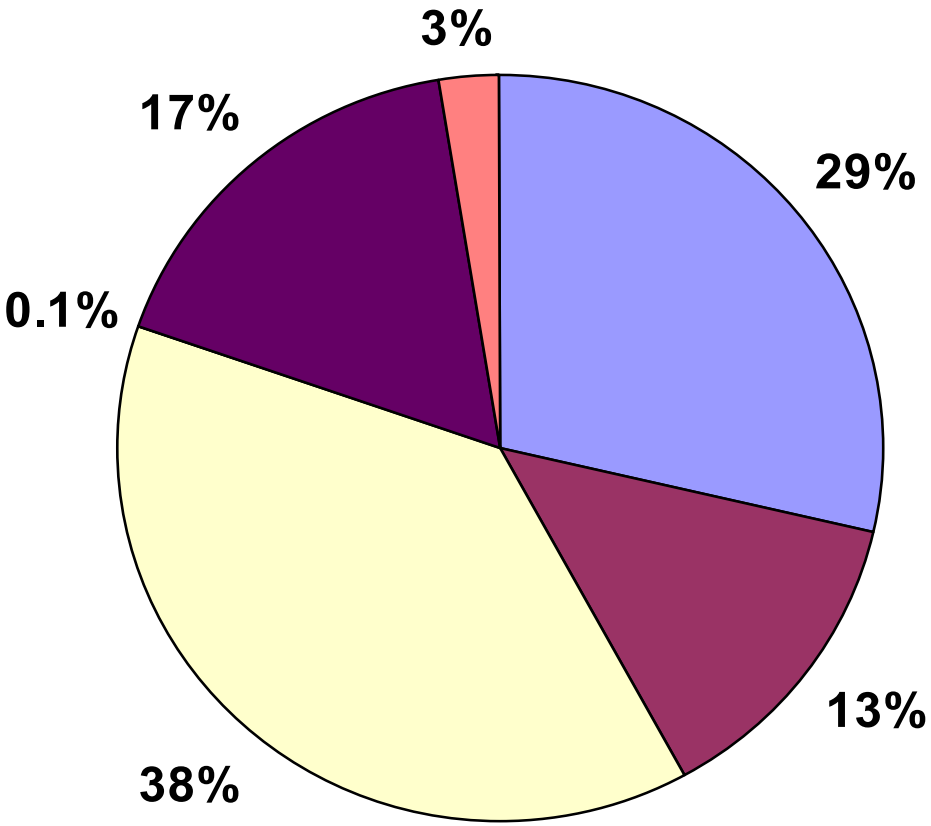
- Tokaimura pilot reprocessing plant (Japan)
  206 kilograms of plutonium unaccounted for
- Plutonium fuel fabrication facility (Japan)
  70 kilograms of plutonium unaccounted for
- Sellafield reprocessing plant (Britain)
  49 kilograms of plutonium unaccounted for in 2003 and 2004 alone
- Approximately 8 kilograms of reactor grade plutonium is sufficient to make a nuclear bomb

Where Do We Get Electricity?



U.S. Electricity Production (2005)

Where Do We Get Electricity?



Florida Electricity Production (2005)

Alternatives to Nuclear Power

- Options for the Near-term (2007-2020)
  - Increased energy efficiency.
  - Conservation and reduction in demand.
  - Greatly expanded utilization of renewable energy resources, particularly solar photovoltaics and large scale wind.

- “Initial lower levels of wind deployment (up to 15 - 20% of the total U.S. electric system capacity) are not expected to introduce significant grid reliability issues.”
  - U.S. National Renewable Energy Laboratory (2005)

Energy versus Energy Services

vs

60 Watts of Power

23 Watts of Power

For the same amount of visible light

Energy versus Energy Services

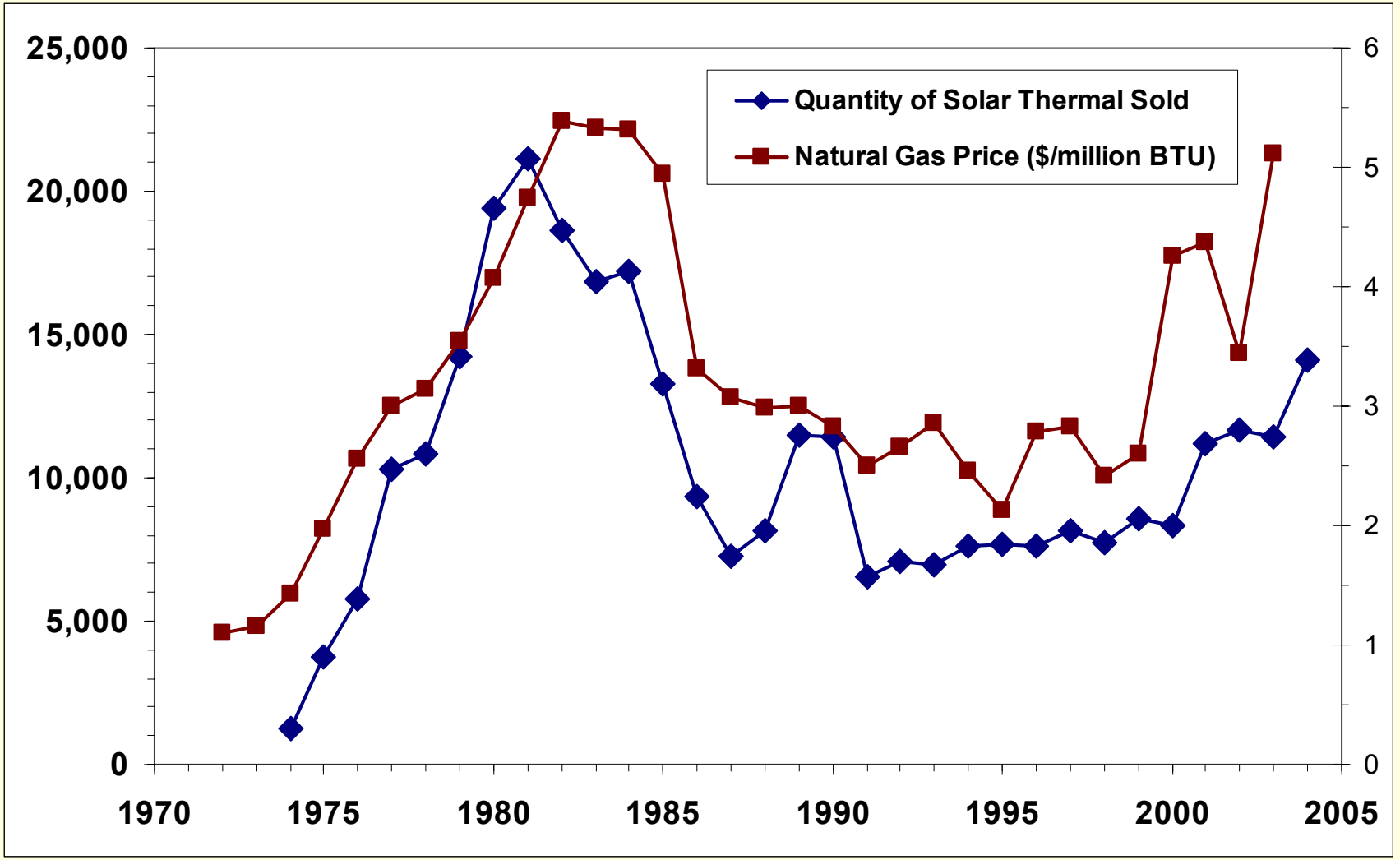
vs

~0.9 units of heat per unit of input

~3 units of heat per unit of input

Energy versus Energy Services

Solar Thermal Water Heating



Alternatives to Nuclear Power

- Options for the Medium-term (2020-2050)
  - Continued expansion of energy efficiency and renewable energy including the addition of some types of sustainable biomass.
  - Fielding of some fossil fuel transition technologies potentially including an expanded use of liquefied natural gas (LNG) in the south and southeastern United States.

Summary and Conclusions

"The potential impact on the public from safety or waste management failure and the link to nuclear explosives technology are unique to nuclear energy among energy supply options. These characteristics and the fact that nuclear is more costly, make it impossible today to make a credible case for the immediate expanded use of nuclear power."

- Massachusetts Institute of Technology, *The Future of Nuclear Power* (2003)

Nuclear Growth Scenarios

- "Global growth scenario"
  - *The Future of Nuclear Power*, MIT (2003)
  - **1,000 GW** of nuclear power online by 2050.
  - Nuclear power supplies 19% of projected demand in 2050. CO_2 emissions continue to rise.
- "Steady-state growth scenario"
  - Emissions of CO_2 from the electricity sector in 2050 remain at year 2000 levels.
  - **1,900 to 3,300 GW** of nuclear power online by 2050 (**2,500 GW** base case).
  - Nuclear power supplies 48% of projected demand in 2050.

Enrichment Capacity Requirements