ALTERNATE ENERGY SOURCES - SOLUTION OF MAJOR PROBLEMS

What are the Facts ?

The Texas Institute for
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INTRODUCTION

This FLYER is an abbreviated summary of INSIGHTS - *Alternate Energy Sources - Solution of Major Problems*. The presentation that follows is in the form of Questions and Answers. More attention is given to nuclear than to the other alternate energy sources because of its importance. Nuclear energy is second only to coal in the production of electricity, and it has the greatest potential for replacing fossil fuels as the major energy source for the production of electricity.

Q **What are the two major energy supply problems facing the United States today?**

A These two major problems are:

- ! The ever increasing shortfall of electric generating capacity;
- ! The buildup of the greenhouse gases and other pollutants resulting from fossil fuel combustion.

As shown in Figure 1, a shortfall of electric power of 185,000 MW (or 185 power plants each having a rating 1,000 MW) is expected by 2010, and by 2020 a shortfall of 335,000 MW is projected.[1]

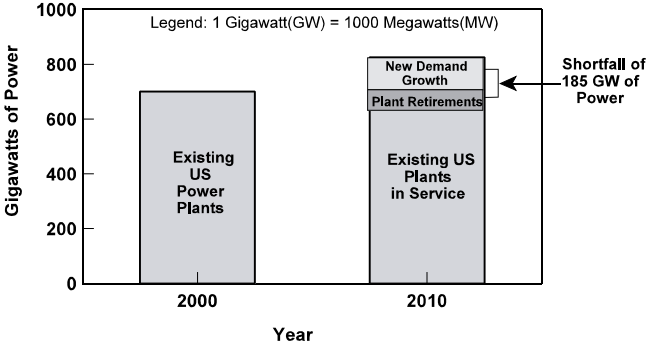

Figure 1. Projected U.S. Power Needs in 2010.[1]

These two problems are interconnected; for to solve the first problem by further use of fossil fuels would increase the severity of the second. Fossil fuels are the major sources of the greenhouse gases (carbon dioxide, methane, and nitrous oxide). That greenhouse gases do cause global warming is a scientific fact. The unanswered questions are how much of the global warming can be attributed to natural causes, and what effects, positive or negative, might global warming have on Texas and the United States? Whatever the effects may be, the United States will probably be pressured into reducing greenhouse gases by its citizenry and world opinion.

Q **What is the solution to these two major problems that will simultaneously increase the supply of electricity and decrease emissions?**

A The solution is to switch from fossil fuels to alternate energy sources whenever and wherever possible. Of these alternate energy sources, only nuclear is suitable for supplying our major industrial, commercial, and industrial needs. The current fuel sources used in the production of electricity in the United States are shown in Figure 2.

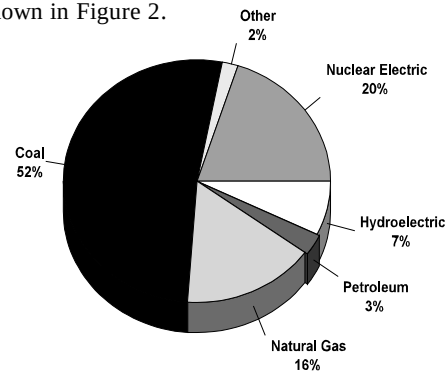

Figure 2. Production of Electricity in the United States, Based on Total Kilowatts Generated in 2000[2]

Q **What are the projected increases in the Renewable Energy Sources (hydropower, geothermal, biomass, wind, and solar)?**

A As shown in Figure 2, hydropower at 7% is not expected to increase appreciably in the future because all of the good sites already have dams on them and because of the growing resistance of the public to the construction of new dams. Geothermal is available only in the Western States and in Alaska and Hawaii. Location and cost have apparently limited the growth of geothermal and is expected to continue to do so. Biomass, wind, and solar have the potential for supplying over 20% of the U.S. electric power needs and some increase can be expected.

Q **Cost of electricity generated by any one source relative to the other sources will be a determining factor in the selection of an energy source for a given power plant. How does the cost of electricity vary with the energy source used in its generation?**

A The estimated and projected costs of electricity generated by use of different fuel sources are shown in Table 1.

Table 1. Summary of Estimated Costs of Electricity from the Major Energy Sources.

Energy Source	Estimate of Cost of Electricity (at busbar), ¢/kWh*
Coal[3]	3.9
Natural Gas[3]	3.6
Nuclear[4,5,6]	3.0
Hydropower[7]	2.4
Geothermal[7]	7.0
Biomass[7]	6.0
Wind [7]	4.0
Solar[7]	8.5

*¢/kWh = cents per kilowatt -hour.

The projected costs of electricity produced by the new designs for nuclear power plants are seen to be competitive with those for coal and natural gas.

Q **What fuel source is being used in most of the new power plants?**

A Natural gas has become the fuel of choice. Over 95% of all the new electric generating plants that went on line in 2001 used natural gas. If this trend continues, it will limit the availability of this valuable resource for the residential, commercial, and industrial sectors of our economy. Continuation of this trend could have a profound impact on those industries such as the chemical industry for which natural gas is a feedstock.

NUCLEAR POWER PLANTS

1. Operation of Nuclear Power Plants

Q **How do nuclear power plants operate?**

A Nuclear plants make use of the heat released by a nuclear reaction to boil water and produce steam that is used to turn a turbine-electric generator as shown in Figure 3.

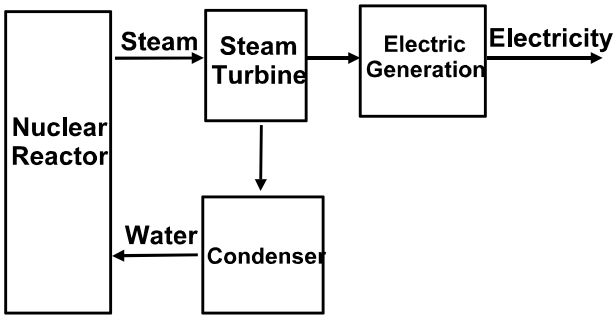

Figure 3. Flow Diagram for a Nuclear Power Plant.

Q **What is the most common nuclear reaction used in present day nuclear reactors?**

A The fissionable element uranium-235(U-235) splits into two fragments and two or more neutrons when struck by a neutron. A sketch of this fission process is shown in Figure 4. Note that the mass of the original atom of U-235 and the neutron that struck it weigh more than the two fragments, strontium-100 and xenon-135, and the two neutrons that were produced as shown in Figure 4. The difference in masses between the reactants and products is converted into energy by the Einstein relationship and appears as heat.

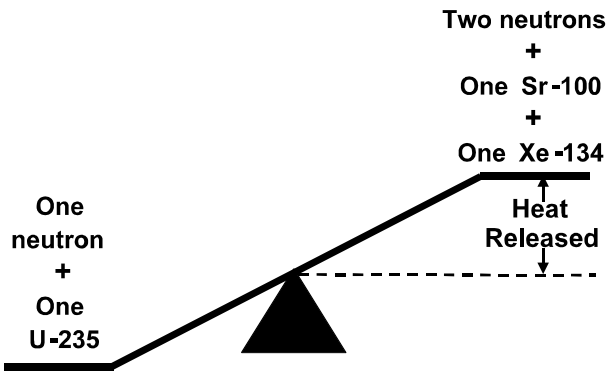

Figure 4. Geometric Representation of a Nuclear Reaction.

Q **How does the energy content of nuclear fuel compare with that of the fossil fuels, oil, coal, and gasoline?**

A According to the nuclear display at the South Texas Project Nuclear Plant at Wadsworth, Texas, one of the fuel pellets (1 centimeter in diameter and 1.5 centimeters in length) shown in Figure 5, has the energy equivalent of 149 gallons of oil, 1,780 pounds of coal, and 157 gallons of regular gasoline.

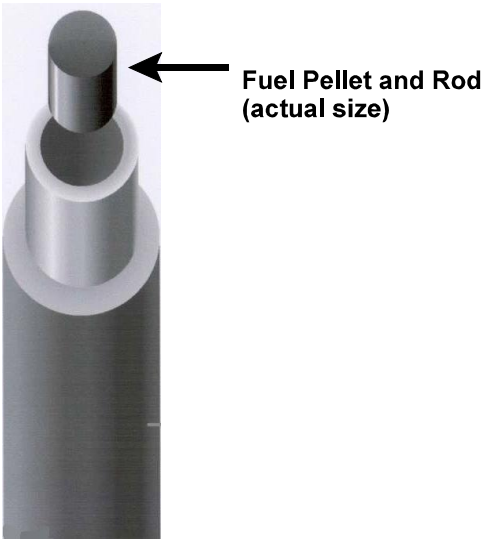

Figure 5. A Fuel Pellet and a Fuel Rod.[8]

2. Spent Reactor Fuel

Q **Of the original enriched uranium-235 (U-235) fuel fed to a nuclear reactor, how much of the U-235 is left in the spent fuel?**

A In a typical nuclear reactor, only 75% of the U-235 is burned, which leaves 25% in the spent fuel along with the plutonium formed from the non-fissionable U-238.

Q **How does the waste from a coal power plant compare with the spent fuel from a nuclear plant of equal power rating?**

A The waste from a coal plant is 5,000,000 times greater than the spent fuel from a nuclear plant. All of the spent fuel generated by all U.S. nuclear reactors since they were started up in the early 1960s amounts to 40,000 tons which would cover a football field to a height of about four yards.

Q **What are some of the proposals that have been made for disposing of the spent fuel?**

A Present plans are to store it at the Yucca Mountain site in Nevada. This site has been approved by both the Congress and the President. However, Senator Peter V. Domenici says that we should regard the spent fuel as an energy reserve and reprocess it at some time in the future to recover the U-235 and the plutonium.[9] The plutonium can be converted to the oxide form and burned with U-235 in reactors.[10] It has been estimated that

reprocessing could extend the supply of U-235 from 250 years to 10,000 years.

Q **Has the public's fear of nuclear energy initially fueled by the Three Mile Island and Chernobyl accidents decreased in recent years?**

A Yes, A recent Gallup public opinion poll showed that there has been a swing from *Opposed* to *Favoring* nuclear energy as shown in Figure 6. Although the Three Mile Island Accident was the most serious accident that has occurred in the U.S. commercial nuclear power industry, no deaths or injuries occurred and only low levels of radiation were released by the accident. Whereas, the Chernobyl accident killed 31 people initially. Most knowledgeable people generally believe that neither of these accidents could have occurred with today's reactor designs. In fact the Chernobyl reactor would have never been licensed in the United States or any other Western Nation.

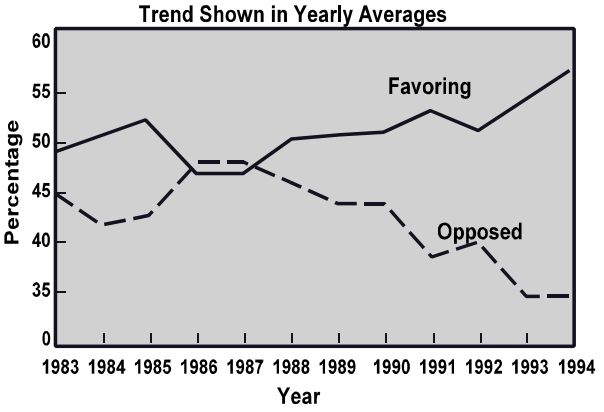

Figure 6. Growing U.S. Support for Nuclear Energy Show in Public Opinion Polls .[10,11]

3. Radiation

Q **How does the radiation from a nuclear power plant compare with that of a coal plant of comparable size?**

A A typical coal plant emits 100 times more radiation than does a nuclear plant.[12] In fact the radiation limit for nuclear plants is so low that the radiation from the granite walls of the United States Capitol is above the limit for nuclear plants, and the Capitol could not be licensed as a nuclear reactor.

4. Terrorism

Q **How well protected are nuclear reactors from terrorists?**

A The walls surrounding a nuclear reactor consist of steel and reinforced concrete that are four to five feet thick. The outside containment walls are two to three feet thick of reinforced concrete.

Q **Can the walls surrounding a nuclear reactor be penetrated by an airplane?**

A No. According to Chapin and 18 other experts who backed up their statement with detailed calculations and field tests in which an unmanned plane flying at 480 miles per hour made only a few centimeters penetration in a simulated reactor wall.[13]

Q **There are some who have expressed concern about terrorists attacks on shipments of spent fuel from a nuclear plant to a storage facility. Just how dangerous is this process?**

A According to Chapin and the 18 other experts, the casks in which the spent fuel is to be shipped are almost indestructible. Virtually nothing can be done to these casks that would cause a significant public hazard.[13]

ECONOMICS OF NUCLEAR POWER PLANTS

Q **How do total plant costs, fuel, and total costs of electricity compare for nuclear, coal, and natural gas power plants?**

A The total plant costs (cost of construction) for a natural gas plant are about one half of those for coal and nuclear, but the cost of fuel for a natural gas plant is about twice that for a coal plant and five times as much as that for a nuclear plant. The resulting cost of electricity from a natural gas plant is about the same as that from coal and nuclear plants.

Type of Plant	Total Plant Costs	Fuel Costs	Total Cost of Electricity
Nuclear	$1,000/kW	0.374¢/kWh	3¢/kWh
Pulverized Coal	$1,173/kW	0.93¢/kWh	3.9¢/kWh
Natural Gas Combined Cycle	$524/kW	1.94¢/kWh	3.6¢/kWh

ENVIRONMENTAL ADVANTAGES OF NUCLEAR POWER PLANTS

Q **What are the downsides to continuing with our present mix of energy sources?**

A
- Regulatory limits on the oxides of nitrogen(NOx) and other criteria pollutants are likely to be extended to other areas throughout the United States.
- Greenhouse gas emissions are likely to be limited in the future because of the demands of our citizenry and world opinion.
- Fine particulate matter can be expected to be regulated in the near future.
- More severe regulations of toxic mercury compounds emitted by coal plants can be expected.

Q **How can all of the above problems be reduced in severity or eliminated?**

A By going to nuclear fuel for all new and replacement power plants.

Q **How much could the greenhouse gases and other pollutants be reduced in the United States by switching from fossil fuels to nuclear fuels in the generation of electricity?**

A There follows an estimate of the reductions that could be achieved, based on the emissions of the fossil fuel plants.

Pollutant	% Reduction in U.S.
NOx	30
SO_2	70
CO_2	30
Toxic Mercury Compounds	Large
Fine Particulate Matter	Substantial
Other Pollutants	Substantial

Q **How can the changeover from fossil fuel to nuclear power plants be carried out such that the economic impacts on other industries and jobs are minimized?**

A This changeover can be carried out by using nuclear energy in all new power plants and in all replacement plants for decommissioned coal and natural gas plants.

Q **How much reduction in greenhouse gases could be achieved by use of the above procedure?**

A If all of the new gas and coal plants on the drawing boards and all replacement plants for decommissioned coal plants were replaced by nuclear plants, the greenhouse emissions could be reduced to well below the Kyoto Accords by 2010, as shown in Figure 7.

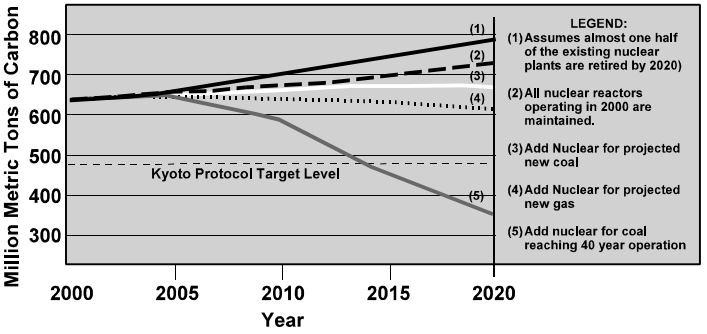

Figure 7. Reduction of Carbon Emissions by Increased Nuclear Energy.[14]

REFERENCES

1. "Annual Energy Outlook 2002 with Projections to 2020, "*Energy Information Administration (EIA)*, (Dec., 2001), **http://www.eia.doe.gov/oiaf/alo/pdf/0383(2002).pdf** .
2. "Production of Electricity in the United States, Based on Total Kilowatts Generated in the Year 2000, *Energy Information Administration (EIA)*, *Electric Power Monthly*, (March 2001).
3. "Market-Based Advanced Power Systems," Final Report, Office of Fossil Energy, U.S. Department of Energy, Washington, D.C. 20585, **www.fe.doe.gov/coalpower/specialrpts/marketsys.shtml.**
4. John W. Winters, "The AP600-Design Certified and Ready to Build," *Nuclear News*, (September, 2000).
5. M.D. Carelli and B. Petrovic, "Next Generation Advanced Reactors," *Nuclear Plant Journal*, pp. 33-36 (May-June 2001).
6. Love, J.W., K.F. Han and T. Mahendralingam, "Design Characteristics of ACR-700, *Twenty Third Annual Conference of the Canadian Nuclear Society*, Toronto, Ontario, Canada, (June 2-5, 2002).
7. "Nuclear Power, A Sustainable Source of Energy," *American Nuclear Society*, (October 2002) **http://www.ans.org/pi/brochures/pdfs/power.pdf**

8. "Used Nuclear Fuel, Handle with Care," *Nuclear Energy Institute*, **www.nei.org**, GP0035, (October, 1999).
9. Senator Peter V. Domenici, "The Need for Nuclear Energy - Four Years After the Harvard Speech," George Bush Convention Center, College Station, Texas (November 19, 2001).
10. Alan E. Waltar, *America the Powerless*, Cogito Books, Madison Wisconsin, (1995).
11. Cambridge Reports/Research Intl., Brushkin/Goldring, and the Gallup Organization; see Reference 9, (1995).
12. Alex Gabbard, "Coal Combustion Nuclear Resource or Danger," **http://www.ornl.gov/ORNLReview/rev26-34/text/colmain.html**, (November 2002).
13. Douglas M. Chapin et al., "Nuclear Power Plants and Their Fuel as Terrorists Targets," *Science*, **297** (20 Sept. 2002).
14. Energy Resources International, 1015 78th Street NW, Suite 650, Washington, D.C. (1997).

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