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FINAL REPORT

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COMPARATIVE EVALUATION OF SOLAR, FISSION,
FUSION, AND FOSSIL ENERGY RESOURCES

PART V

CONCLUSIONS AND RECOMMENDATIONS

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"Over periods of many millions of years plants covered the earth, converting the energy of sunlight into living tissue, some of which became buried in the depths of the earth to produce deposits of coal, oil, and natural gas. During the past few decades Man has found many valuable uses for these complex chemical substances, manufacturing from them plastics, textiles, fertilizers, and the varied end products of the petrochemical industry. Each decade sees increasing uses for these products. Coal, oil and gas are non-renewable natural resources which will certainly be of great value to future generations, as they are to ours.

However, Man has found another use for these valuable chemicals from the earth, a use other than the creation of the products that add so much to our standard of living. That is to burn them. To burn them in huge and ever increasing quantities to power the machines of society and provide heat. They are being burned at such an incredible rate that in a few short decades the world reserves of natural gas may be depleted, decades later the oil will be gone, and in a century or two the world will also be without coal. Undoubtedly successive generations of humanity after that time will decry the excesses of the present generation in selfishly destroying these valuable resources without regard for the welfare of their descendants.

The rapid depletion of non-renewable fossil resources need not continue, since it is now or soon will be technically and economically feasible to supply all of Man's energy needs from the most abundant energy source of all, the sun. Sunlight is not only inexhaustible, but it is the only energy source which is completely non-polluting. The land area required to provide all our energy is a small fraction of the land area required to

produce our food; and the land best suited for collecting solar energy, rooftops and deserts, is the land least suited for other purposes. It is time for the United States, which led the world in the development of atomic energy and in putting men on the moon, to mount an equally massive effort to usher in the Solar Age. With such a massive effort our country can offer the world the technology for the economical utilization of solar energy in all its varied forms - photovoltaic, direct solar-thermal, renewable fuels, ocean thermal, and winds. Then we can conserve our valuable non-renewable fossil resources for many future generations to enjoy, and we can all live in a world of abundant energy without pollution".¹

Nuclear energy will be increasingly important in the coming decades, and should also be pursued with utmost emphasis placed on safety and environmental concerns. Waste heat can be used productively in northern climates. Possibilities for disposing radwaste in space away from the earth should be pursued. Nuclear reactors can provide power in large chunks, and can propel large ships and submarines. Nuclear and solar together, and if necessary solar alone, can eventually supply all of Man's energy needs.

The adverse environmental impacts of continued fossil fuel combustion are well known, and may be even more far reaching than currently thought. The air pollution choking many of our cities is almost entirely from the combustion of fossil fuel. Coal mining is a hazardous, unhealthy occupation and many people have lost their lives extracting these materials from the depths of the earth. Oil spills have contaminated beaches and killed wildlife. Several oil spills, releasing between 10,000 tons and 100,000 tons of oil, have had a strongly adverse effect on the ecology of the area where they occurred. Oil is toxic to many marine organisms. Worldwide, about a million tons per year is spilled from various oil operations, and in the

U. S. alone another million tons of waste motor oil is dumped annually. Except for obvious localized effects when major spills occur, it has not known what the long term effect of this continued large scale dumping will be. The author once had his home destroyed by the rupture of a tank of butane gas. But in addition to these known safety and environmental hazards, the combustion of fossil fuels is causing a increase in the carbon dioxide content of the atmosphere, which could cause major worldwide climatological changes over the next few decades.

Carbon dioxide is normally not considered a pollutant since it occurs naturally in the earth's atmosphere. Huge quantities of CO₂ have been released into the atmosphere during the past few decades from the combustion of fossil fuels. It is the only combustion product whose increase in the atmosphere has been documented on a worldwide basis. Precise measurements by C D Keeling of the Scripps Institute of Oceanography showed that the carbon dioxide content increased by six parts per million between 1958 and 1968. It appears that, since 1860, when fossil fuels began to be burned in large amounts, the carbon dioxide concentration in the atmosphere has increased from 290 ppm to about 320 ppm. Reasonable projections indicate an increase to about 400 ppm by the turn of the century and 540 ppm by 2020.² The concentration could rise as high as 1500 ppm during the next century.

Carbon dioxide is not expected to have any direct toxic effects on man or animal life at these levels, although no long-term studies have been conducted. Many types of plants have been found to grow better with increased levels of carbon dioxide in greenhouses. The major effect of the CO₂ increase will be on the thermal balance of the earth.

CO₂ has strong absorption levels in the infrared region between 12 and 18 microns. This is the spectral region where most of the thermal energy

radiating from the earth into space is concentrated. The increased CO₂ increases atmospheric absorption of this radiation, and it is reradiated at the much lower temperature of the upper atmosphere. This is known as the "greenhouse effect". CO₂ does not affect the solar energy received by the earth, but reduces energy radiated from the earth, so the result is an increase of the earth's temperature. Several investigators have calculated what this temperature rise would be. In 1956 Plass³ calculated the effect of doubling the CO₂ content of the atmosphere and predicted a rise of 3.6°C. More recently, Manabe and Wetherald performed more extensive calculations and predicted that an increase in CO₂ content from 300 to 600 ppm would increase the average surface temperature by 2.36°C, assuming fixed relative humidity and average cloudiness. A worldwide temperature increase of this magnitude would be expected to cause considerable melting of the polar ice caps, resulting in a 100 to 200 foot rise in the level of the oceans. This would cause most coastal cities to be flooded.

There is also some concern about what is called the multiplier effect. The oceans contain 60 times as much CO₂ as the atmosphere, and this CO₂ is in equilibrium with the atmosphere at the present temperature of the oceans. If doubling of the atmospheric CO₂ causes a warming trend which results in an increase of the temperature of the oceans, then the solubility of CO₂ in the oceans is reduced. Thus, warming of the oceans could cause large additional amounts of CO₂ to be released, causing the temperature to increase still further.

The problem of predicting the effects of energy production on the thermal balance of the earth is complicated even further, due to the effects of particulates. There is some uncertainty at present as to whether particulates released into the atmosphere tend to increase or decrease the

temperature of the earth, but most researchers believe that particulates tend to lower the earth's temperature by scattering sunlight back into space. Barrett⁴ et al. used an estimate of 4 million tons for particulates in the atmosphere and calculated the global mean temperature to be 0.8°C below what it would be in the absence of any particles. Doubling the particulate loading would result in a further decrease of 1°C. Thus, if aerosol and CO₂ concentrations were to increase at the same rate, one might expect a net warming trend. If the aerosol doubling time is much shorter than that for CO₂, a cooling trend could result. The effects of high altitude particulate emissions by jet aircraft introduce additional uncertainty, since their effects are difficult to take into account.

Thus, the air pollution resulting from energy production has a wide variety of effects on man and on his environment. Techniques are being developed and applied for reducing emissions of sulfur dioxide, the nitrogen oxides, particulates, carbon monoxide and hydrocarbons. The release of vast quantities of CO₂ into the atmosphere will continue unabated as long as fossil fuels are burned for large scale energy generation.

In view of these and other considerations, it is recommended that the United States establish the goal of eliminating the combustion of fossil fuels in this century. In order to achieve this goal, while providing abundant supplies of energy to the people of this country, the following actions should be taken.

1. Accelerate the construction of nuclear reactors and the development and deployment of nuclear breeder reactors without sacrificing safety. Each vender should be allowed to market several AEC-approved standardized plants which can be erected on a site within 4 years of contract initiation.

2. Launch a crash program to develop and install solar energy systems with a funding level of about half that devoted to nuclear energy. Recommendations for the required R&D are given in Part I of this report.
3. Pursue all other energy alternatives, such as geothermal and fusion, at appropriate funding levels.
4. For the immediate energy crisis coal must be substituted for gas and oil whenever possible. Power plants should burn coal and, as an interim measure, use tall stacks for SO₂ control.⁵

If these actions are taken, we can have all the energy we need, we can become energetically self-sufficient, and we can conserve our valuable non-renewable fossil resources for many future generations to enjoy.

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