Exhibit 12

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WHAT TO DO ABOUT GREENHOUSE WARMING: LOOK BEFORE YOU LEAP

S. Fred Singer
Roger Revelle
Chauncey Starr

Greenhouse warming has emerged as one of the most complex and controversial environmental and foreign-policy issues of the 1990s.

It is an environmental issue because carbon dioxide (CO_2), generated from the prolific burning of oil, gas and coal, is thought to enhance, by trapping heat in the atmosphere, the natural greenhouse effect that has kept the planet warm for billions of years. Some scientists predict drastic climatic changes in the 21st century.

The scientific base for a greenhouse warming is too uncertain to justify drastic action at this time.

It is a foreign-policy issue because, for a number of reasons, the United States has taken a more cautious approach to dealing with CO_2 emissions than have many industrialized nations. Wide acceptance of the Montreal Protocol, which limits and rolls back the manufacture of chlorofluorocarbons (CFCs) to protect the ozone layer, has encouraged environmental activists at international conferences the past three years to call for similar controls on CO_2 from fossil-fuel burning.

These activists have expressed disappointment with the White House for not supporting immediate action. But should the United States assume "leadership" in a hastily-conceived campaign that could cripple the global economy, or would it be more prudent to assure first, through scientific research, that the problem is both real and urgent?

We can sum up our conclusions in a simple message: *The scientific base for a greenhouse warming is too uncertain to justify drastic action at this time.*

There is little risk in delaying policy responses to this century-old problem since there is every expectation that scientific understanding will be substantially improved within the next decade. Instead of premature and likely ineffective controls on fuel use that would only slow down but not stop the further growth of CO_2, we may prefer to use the same resources—trillions of dollars, by some estimates—to increase our economic and technological resilience so that we can then apply specific remedies as necessary to reduce climate change or to adapt to it.

That is not to say that prudent steps cannot be taken now; indeed, many kinds of energy conservation and efficiency increases make economic sense even without the threat of greenhouse warming.

THE SCIENTIFIC BASE

The scientific base for greenhouse warming (GHW) includes some facts, lots of uncertainty and just plain lack of knowledge—requiring more observations, better theories and more extensive calculations. Specifically, there are reliable measurements of the increase in so-called greenhouse gases in the earth's atmosphere, presumably as a result of human activities. There is uncertainty about the strength of sources and sinks for these gases, i.e., their rates of generation and removal. There is major uncertainty and disagreement about whether this increase has caused a change in the climate during the last century. There is also disagreement in the scientific community about predicted future changes as a result of further increases in greenhouse gases. The models used to calculate future climate are not yet good enough because the climate-balancing processes are not sufficiently understood, nor are they likely to be good enough until we gain more understanding through observations and experiments.

As a consequence, we cannot be sure whether the

S. Fred Singer ('57) is professor of environmental sciences at the University of Virginia and served as the first director of the U.S. weather satellite program, among several government positions.

Roger Revelle ('43), professor of science and public policy at the University of California at San Diego, is former director of the Scripps Institution of Oceanography. He is a member of the National Academy of Sciences and last year received the National Medal of Science.

Chauncey Starr ('68) is the president emeritus of the Electric Power Research Institute and former dean of engineering at the University of California at Los Angeles. He is a member of the National Academy of Engineering. Last year he received the National Medal of Technology.

next century will bring a warming that is negligible or a warming that is significant. Finally, even if there are a global warming and associated climate changes, it is debatable whether the consequences will be good or bad; likely some places on the planet would benefit, some would suffer.

GREENHOUSE GASES (GHG)

It has been common knowledge for about a century that the burning of fossil fuels would increase the normal atmospheric content of carbon dioxide (CO_2), causing an enhancement of the natural greenhouse effect and a possible warming of the global climate. Advances in spectroscopy in the last century produced evidence that CO_2—and other molecules made up of more than two atoms—absorb infrared radiation and thereby would impede the escape of such heat radiation from the earth's surface. In fact, it is the greenhouse effect from naturally occurring CO_2 and water vapor (H_2O) that has warmed the earth's surface for billions of years; without the natural greenhouse effect ours would be a frozen planet without life.

Precise measurements of the increase in atmospheric CO_2 date to the International Geophysical Year of 1957-58. More recently it has been discovered that other greenhouse gases, i.e., gases that absorb strongly in the infrared, have also been increasing—at least partly as a result of human activities. They currently produce a greenhouse effect nearly equal to that of CO_2, and could soon outdistance it.

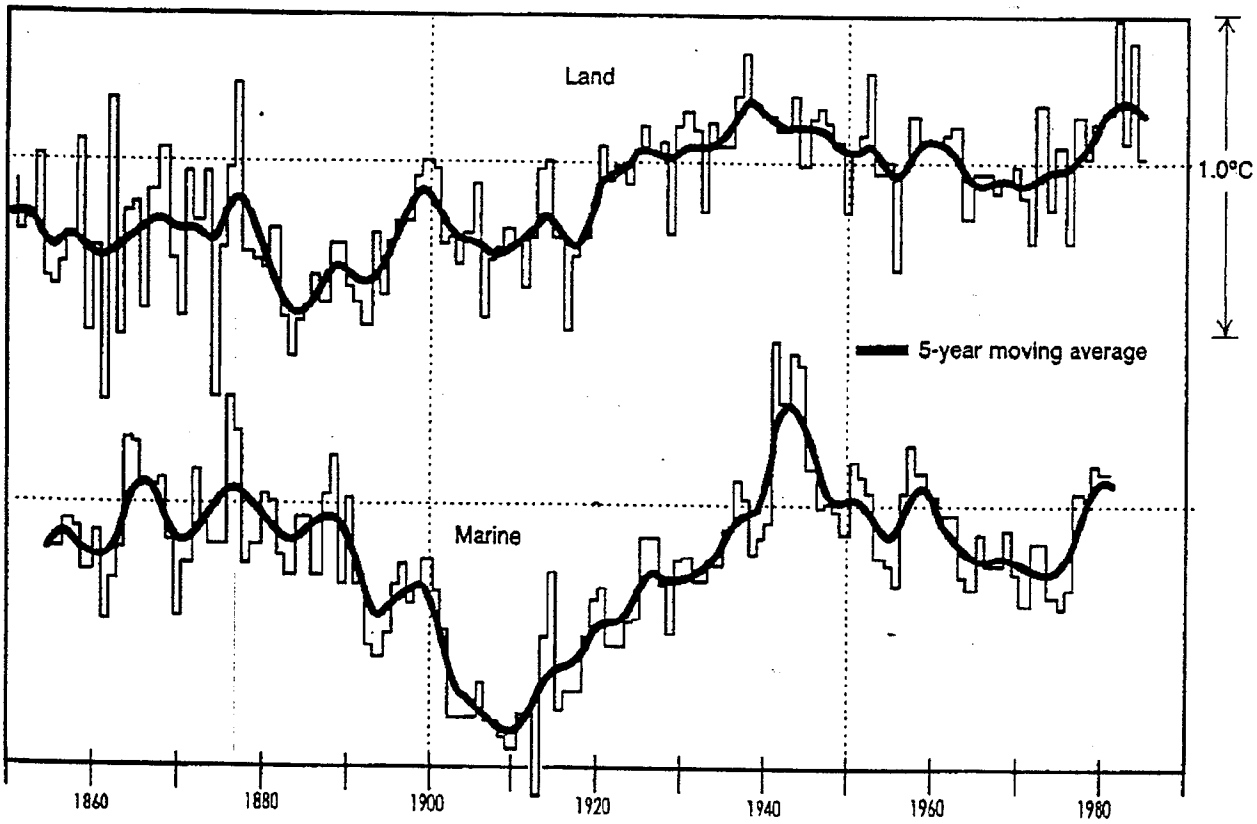
Methane (CH_4) is produced in large part by sources that relate to population growth; among these are rice paddies, cattle, landfills, forest fires, coal mines and oil field operations. Indeed, methane, now 20 percent of the greenhouse gas effect but growing twice as fast as CO_2, has more than doubled since pre-industrial times; it would soon become the most important greenhouse gas if CO_2 emissions were to stop.

Nitrous oxide (N_2O) has increased by 10 percent, most likely because of soil bacterial action promoted by the increased use of nitrogen fertilizers.

Ozone (O_3) from urban air pollution adds about 10 percent to the global greenhouse effect. It may decrease in the U.S. as a result of Clean Air legislation but increase in other parts of the world.

CFCs manufactured for use in refrigeration, air

Yearly Average Temperatures in the Northern Hemisphere



Note the major increases before 1938, when greenhouse gas concentrations were low, and the sustained cooling to 1975. Though temperatures remained near record levels during the 1980s, there was no clear upward trend.

Source: Nature 322

conditioning and industrial processes are making an important contribution but will soon be replaced by less-polluting substitutes.

Water vapor (H_2O) turns out to be the most effective greenhouse gas by far. It is not manmade, but is assumed to amplify the warming effects of the gases produced by human activities. We don't really know whether H_2O has increased in the atmosphere or whether it will increase in the future—although that's what all the model calculations assume. Indeed, predictions of future warming depend not only on the amount but also on the horizontal and especially the vertical distribution of H_2O, and on whether it will be in the atmosphere in the form of a gas or as liquid cloud droplets or as ice particles. The current computer models are not complete enough to test these crucial points.

THE CLIMATE RECORD

The issue now is whether the 25 percent increase of CO_2 in the atmosphere, mainly since World War II, calls for immediate and drastic action to limit and roll back global energy use. Taking account of increases in the other trace gases that produce greenhouse effects, we have already gone halfway to an effective GHG doubling—something that cannot be reversed in our lifetime—and, according to the prevailing theory, locked in a temperature increase of about 1.6 degrees Celsius.

But has there been a climate effect caused by the increase of greenhouse gases in the last decades? The data are ambiguous to say the least. Advocates for immediate action profess to see a global warming of about 0.5 degrees C since 1880, and point to record global temperatures in the 1980s and the warmest year on record in 1990. Most atmospheric scientists tend to be cautious, however; they call attention to the fact that the greatest temperature increase occurred *before* the major rise in greenhouse gas concentration. It was followed by a quarter-century decrease between 1940 and 1965 when concern arose about an approaching ice age! Following a sharp increase during 1975-80, there has been no clear upward trend during the 80s despite some very warm individual years and record GHG increases. Similarly, global atmospheric (rather than surface) temperatures measured by Tiros weather satellites show no trend in the last decade.

Scientists Kirby Hanson, Thomas Karl and George Maul of the National Oceanic and Atmospheric Administration (NOAA) find no overall warming in the U.S. temperature record, contrary to the global record assembled by James Hansen of the National Aeronautics and Space Administration (NASA). Using a technique that eliminates urban "heat islands" and other local distorting effects, they confirm the temperature rise before 1940, followed, however, by a general decline. Reginald Newell and colleagues at the Massachusetts Institute of Technology (MIT) report no substantial change in the global sea-surface temperature in the past century; yet the ocean, because of its much greater heat inertia, should control any atmospheric climate change.

Perhaps most interesting are the NOAA studies that document a relative rise in night temperatures in the U.S. in the last 60 years, while daytime values stayed the same or declined. This is just what one would expect from the increase in atmospheric greenhouse gas concentration. But its consequences, as University of Virginia climatologist Patrick Michaels and others have pointed out, are benign: A longer growing season, fewer frosts, no increase in soil evaporation.

It is therefore fair to say that we haven't seen the huge greenhouse warming, of between 0.7 and 2.5 degrees C, expected from the conventional theories. Why not? This scientific puzzle has many suggested solutions:

- The warming has been "soaked up" by the ocean and will appear after a delay of some decades. Plausible—but there is no evidence to support this theory until deep-ocean temperatures are measured on a routine basis, as suggested by Scripps Institution oceanographer Walter Munk. Feasibility tests are currently underway, using a sound source at Heard Island in the South Indian Ocean and a global network

ANOTHER ICE AGE COMING?

Global temperatures have been declining since the dinosaurs roamed the earth some 70 million years ago. About 2 million years ago, a new "ice age" began—most probably as a result of the drift of the continents and the buildup of mountains. Since that time, the earth has seen 17 or more cycles of glaciation, interrupted by short (10,000 to 12,000 years) interglacial or warm periods. We are now in such an interglacial interval, the Holocene, that started 10,800 years ago. The onset of the next glacial cycle cannot be very far away.

It is believed that the length of a glaciation cycle, about 100,000 to 120,000 years, is controlled by small changes in the seasonal and latitudinal distribution of solar energy received as a result of changes in the earth's orbit and spin axis. While the theory can explain the timing, the detailed mechanism is not well understood—especially the sudden transition from full glacial to interglacial warming. Very likely an ocean-atmosphere interaction is triggered and becomes the direct cause of the transition in climate.

The climate record also reveals evidence for major climatic changes on time scales shorter than those for astronomical cycles. During the past millennium, the earth experienced a "climate optimum" around 1100 A.D., when Vikings found Greenland to be green and Vinland (Labrador?) able to support grape growing. The "Little Ice Age" found European glaciers advancing well before 1600 and suddenly retreating starting in 1860. The warming reported in the global temperature record since 1880 may thus simply be the escape from this Little Ice Age rather than our entrance into the human greenhouse.

of microphones, but data over at least a decade will be needed to provide an answer.

• The warming has been overestimated by the existing models. Meteorologists Hugh Ellsaesser (Livermore National Laboratory) and Richard Lindzen (MIT) propose that the models do not take proper account of tropical convection and thereby overestimate the amplifying effects of water vapor over this important part of the globe. Other atmospheric scientists suggest that the extent of cloudiness may increase as ocean temperatures try to rise and as evaporation increases. Clouds reflect incoming solar radiation; the resultant cooling could offset much of the greenhouse warming. Most intriguing has been the suggestion by British researchers that sulfates from smokestacks—the precursors of acid rain—may have played a role in producing an increase in bright stratocumulus clouds.

• The warming exists as predicted, but has been hidden by offsetting climate changes caused by volcanoes, solar variations, or other natural causes as yet unspecified—such as the cooling from an approaching ice age. (Some, like Robert Balling of Arizona State University, consider the warming before 1940 to be a recovery from the "Little Ice Age" that prevailed from 1600 to about 1850; if correct, this would imply no net warming at all in the past century due to GHW.) Each hypothesis has vocal proponents—and opponents—in the scientific community; but the jury is out until better data become available.

MATHEMATICAL MODELS

Indeed, there is much to complain about when it comes to predictions of future climate, but there is really no alternative to global climate models. "Models are better than handwaving," claims Stephen Schneider of the National Center for Atmospheric Research (NCAR)—but how much better? Half a dozen of these General Circulation Models (GCM) are now running, mostly in the United States. Even though they use similar basic atmospheric physics, they give different results. There is general agreement among them that there should be global warming; but, with an effective GHG doubling, the calculated average global increase ranges between 1.5 and 4.5 degrees C! These predicted values were unchanged for many years, then crept up and have recently dropped back to the lower end of the range. Just during 1989 some of the modelers cut their predictions in half as they tried to include clouds and ocean currents in a better way. Further, there is serious disagreement among the models on the regional distribution of this warming and on where the increased precipitation will go.

The models are "tuned" to give the right mean temperature and seasonal temperature variation, but they fall short of modeling other important atmospheric processes, such as the poleward transport of energy via ocean currents and atmosphere from its source in the equatorial region. Nor do they encompass longer-scale processes that involve the deep layers of the oceans or the ice and snow in the earth's cryosphere, nor fine-scale processes that involve convection, cloud formation, boundary layers, or that depend on the earth's detailed topography.

There are serious disagreements also between model results and the actual experience from the climate record of the past decade, according to Ellsaesser. Existing models retroactively predict a strong warming of the polar regions and of the tropical upper atmosphere, and less warming in the southern hemisphere than the northern—all contrary to observations. Yet there is hope that research, including satellite observations and ocean data, will provide many of the answers within this decade. Faster computers will also allow higher spatial resolution and incorporate the detailed and more complicated interactions that are now neglected.

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IMPACTS OF CLIMATE CHANGE

Assume what we regard as the most likely outcome: A modest average warming in the next century—well below the normal year-to-year variation—and mostly at high latitudes and in the winter. Is this necessarily bad? One should perhaps recall that only a decade ago when climate *cooling* was a looming issue, economists of the National Academy of Sciences' National Research Council calculated a huge national cost associated with such cooling. More to the point perhaps, actual climate cooling, experienced during the Little Ice Age or in the famous 1816 New England "year without a summer," caused large agricultural losses and even famines.

If cooling is bad, then warming should be good, it would seem—provided the warming is slow enough so that adjustment is easy and relatively cost-free. Even though crop varieties are available that can benefit from higher temperatures with either more or less moisture, the soils themselves may not be able to adjust that quickly. But agriculturalists, like Sherwood Idso of the U. S. Department of Agriculture and Yale professor William Reifsnyder, generally expect that with increased atmospheric CO_2—which is, after all, plant food—plants will grow faster and need less water. The warmer night temperatures suggested by Patrick Michaels, using the data of Thomas Karl,

translate to longer growing seasons and fewer frosts. Increased global precipitation should also be beneficial to plant growth.

Keep in mind also that year-to-year changes at any location are far greater and more rapid than what might be expected from greenhouse warming; and nature, crops and people are already adapted to such changes. It is the extreme climate events that cause the great ecological and economic problems: Crippling winters, persistent droughts, extreme heat spells, killer hurricanes and the like. But there is no indication from modeling or from actual experience that such extreme events *would* become more frequent if greenhouse warming becomes appreciable. The exception might be tropical cyclones, which—Balling and Randall Cerveney argue—would be more frequent but weaker, would cool vast areas of the ocean surface and increase annual rainfall. In sum, climate models predict that global precipitation should increase by 10 to 15 percent, and polar temperatures should warm the most, thus reducing the driving force for severe winter-weather events.

We can be putting into effect policies and pursue approaches that make sense even if the greenhouse effect did not exist.

There is finally the question of sea-level rise as glaciers melt—and fear of catastrophic flooding. The cryosphere certainly contains enough ice to raise sea level by 100 meters; and, conversely, during recent ice ages, enough ice accumulated to drop sea level 100 meters below the present value. But these are extreme possibilities; tidal-gauge records of the past century suggest that sea level has risen modestly, about 0.3 meters. But the gauges measure only *relative* sea level, and many of the gauge locations have dropped because of land subsidence. Besides, the test locations are too highly concentrated geographically, mostly on the U.S. East Coast, to permit global conclusions. The situation will improve greatly, however, in the next few years as precise absolute global data become available from a variety of satellite systems.

In the meantime, satellite radar-altimeters have already given a surprising result. As reported by NASA scientist Jay Zwally in *Science*, Greenland ice-sheets are gaining in thickness—a net increase in the ice stored in the cryosphere and an inferred *drop* in sea level—leading to somewhat uncertain predictions about future sea level. Modeling results suggest little warming of the Antarctic Ocean because the heat is convected to deeper levels. It is clearly important to verify these results by other techniques and also get more direct data on current sea-level changes.

Summarizing the available evidence, we conclude that even if significant warming were to occur in the next century, the net impact to the entire planet may well be beneficial—with some regions enjoying improved climate, some encountering worse. This would be even more true if the long-anticipated ice age were on its way.

In view of the uncertainties about the degree of warming, and the even greater uncertainty about its possible impact—what should we do? During the time that an expanded research program reduces or eliminates these uncertainties, we can be putting into effect policies and pursue approaches that make sense even if the greenhouse effect did not exist.

ENERGY POLICIES

Conserve energy by discouraging wasteful use globally. Conservation can best be achieved by pricing rather than by command-and-control methods. If the price can include the external costs that are avoided by the user and loaded onto someone else, this strengthens the argument for proper pricing. The idea is to have the polluter or the beneficiary pay the cost. An example would be peak-pricing for electric power. Yet another example, appropriate to the greenhouse discussion, is to increase the tax on gasoline to make it a true highway-user fee—instead of having most capital and maintenance costs paid by various state taxes, as is done now. Congress has lacked the courage for such a direct approach, preferring instead regulation that is mostly ineffective and produces large indirect costs for the consumer.

Improve efficiency in energy use. Energy efficiency should be attainable without much intervention, provided it pays for itself. A good rule of thumb: If it isn't economic, then it probably wastes energy in the process and we shouldn't be doing it. Over-conservation can waste as much energy as under-conservation. (For example, destroying all older cars would certainly raise the fuel efficiency of the fleet, but replacing these cars would consume more energy in their manufacture.) If energy is properly priced, i.e., not subsidized, the job for government is to remove the institutional and other road blocks:

- Provide information to consumers, especially on life-cycle costs for home heating, lighting, refrigerators and other appliances.
- Encourage—but not force—the turnover and replacement of older, less efficient (and often more polluting) capital equipment: Cars, machinery, power plants. Some existing policies that make new equipment too costly go counter to this goal.
- Stimulate the development of more efficient systems, such as a combined-cycle power plant or a more efficient internal-combustion engine.

Use non-fossil-fuel energy sources wherever this makes economic sense. Nuclear power is competitive now, and in many countries is cheaper than fossil-fuel power—yet it is often opposed on environmental

grounds. The problems cited against nuclear energy, such as disposal of spent nuclear fuel, are more political and psychological than technical. To address safety concerns, nuclear engineers are focusing on an "inherently" safe reactor. Nuclear energy from fusion rather than from fission may be a longer-term possibility, but the time horizon is uncertain.

Solar energy, and other forms of renewable energy, should also become more competitive as their costs drop and as fossil-fuel prices rise. Solar energy applications are restricted not only by cost; solar energy is both highly variable and very dilute; it takes a football field of solar cells to supply the total energy allocated to the average U.S. household. Wind energy and biomass are other forms of solar energy, competitive in certain applications. Schemes to extract energy from temperature differences in the ocean have been suggested as inexhaustible sources of non-polluting hydrogen fuel, once we solve the daunting technical problems.

DIRECT INTERVENTIONS

If greenhouse warming ever becomes a problem, there are a number of proposals for removing CO_2 from the atmosphere. Rebuilding forests is widely talked about, but may not be cost-effective; yet natural expansion of boreal forests—those in high-latitude regions—in a warming climate would sequester atmospheric CO_2. A novel idea, proposed by California oceanographer John Martin, is to fertilize the Antarctic Ocean and let plankton growth do the job of converting CO_2 into bio-material. The limiting trace nutrient may be iron which could be supplied and dispersed economically.

If all else fails, there is always the possibility of putting "venetian blind" satellites into earth orbit to modulate the amount of sunshine reaching the earth. These satellites could also generate electric power and beam it to the earth, as originally suggested by Peter Glaser of A. D. Little. Such schemes may sound farfetched, but so did many other futuristic projects in the past—and in the present, like covering the Sahara with solar cells or Australia with trees.

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CONCLUSION

Drastic, precipitous—and, especially, unilateral—steps to delay the putative greenhouse impacts can cost jobs and prosperity and increase the human costs of global poverty, without being effective. Stringent controls enacted now would be economically devastating—particularly for developing countries for whom reduced energy consumption would mean slower rates of economic growth—without being able to delay greatly the growth of greenhouse gases in the atmosphere. Yale economist William Nordhaus, one of the few who has been trying to deal quantitatively with the economics of the greenhouse effect, has pointed out that "... those who argue for strong measures to slow greenhouse warming have reached their conclusion without any discernible analysis of the costs and benefits...." It would be prudent to complete the ongoing and recently expanded research so that we will know what we are doing before we act. "Look before you leap" may still be good advice. ■