Antigraha

WHERE THE WORLD MEETS

Global climate

FACSIMILE MESSAGE

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TO: NANCY MAYNARD USA (202) 395-3719

COMPANY: OFFICE OF SCIENCE & TECHNOL. POLICY...

FROM: BOB WATSON & DAN ALBRITTON, Room 201

DEPARTMENT: IPCC WG 1., WINDSOR, U.K.

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MESSAGE:

We are told ~~that this~~ second ~~text~~ is much closer to what she actually said. The consistency with the Report is better. You will also note more commitment to action.

Dan & Bob

(IF YOU HAVE ANY TROUBLE WITH THIS TRANSMISSION PLEASE DO NOT HESITATE TO CONTACT US FOR RE-TRANSMISSION OF FAX)

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WICK LANE

PRIME MINISTER'S SPEECH AT THE OPENING OF THE HADLEY CENTRE FOR CLIMATE PREDICTION AND RESEARCH ON FRIDAY 25 MAY

MANY OF US HAVE BEEN WORRIED FOR SOME TIME NOW ABOUT THE ACCUMULATING EVIDENCE OF DAMAGE TO THE GLOBAL ENVIRONMENT AND THE CONSEQUENCES FOR LIFE ON EARTH AND FOR FUTURE GENERATIONS. I SPOKE ABOUT THIS TO THE ROYAL SOCIETY IN 1988 AND TO THE UNITED NATIONS GENERAL ASSEMBLY IN NOVEMBER LAST YEAR.

TODAY, WITH THE PUBLICATION OF THE REPORT OF THE INTER-GOVERNMENTAL PANEL ON CLIMATE CHANGE, WE HAVE AN AUTHORITATIVE EARLY WARNING SYSTEM: AN AGREED ASSESSMENT FROM SOME THREE HUNDRED OF THE WORLD'S LEADING SCIENTISTS OF WHAT IS HAPPENING TO THE WORLD'S CLIMATE. CONGRATS TO DR. HOUGHTON

THEY CONFIRM THAT GREENHOUSE GASES ARE INCREASING SUBSTANTIALLY AS A RESULT OF MAN'S ACTIVITIES: THAT THIS WILL WARM THE EARTH'S SURFACE WITH SERIOUS CONSEQUENCES FOR US ALL: AND THAT THESE CONSEQUENCES ARE CAPABLE OF PREDICTION. WE WANT TO PREDICT THEM MORE ACCURATELY. THAT'S WHY WE ARE OPENING THIS CENTRE TODAY.

WE HAVE, THEREFORE, A REPORT OF HISTORIC SIGNIFICANCE. IT'S NOT SOMETHING ARCANE OR REMOTE FROM EVERYDAY CONCERNS: WHAT IT PREDICTS WILL AFFECT OUR DAILY LIVES. GOVERNMENTS AND INTERNATIONAL ORGANISATIONS IN EVERY PART OF THE WORLD ARE GOING TO HAVE TO SIT UP AND TAKE NOTICE AND RESPOND.

OF COURSE THERE IS A LOT MORE THAT WE STILL NEED TO FIND OUT. BUT IF THE PANEL'S PREDICTIONS ARE BROADLY RIGHT, THEN THE WORLD COULD BECOME HOTTER THAN AT ANY TIME IN THE LAST 100,000 YEARS.

WE KNOW THAT THERE HAVE BEEN MAJOR CHANGES IN THE WORLD'S CLIMATE AND ENVIRONMENT IN THE PAST. FOR INSTANCE, IN THIS COUNTRY YOU COULD GROW VINES AS FAR NORTH AS EDINBURGH IN ROMAN TIMES, AND FOSSILS OF SERPENTS HAVE BEEN FOUND FROM EVEN MORE

BUT THE CHANGES WHICH WE ARE TALKING ABOUT NOW WILL OCCUR AT A FASTER RATE THAN ANYTHING OUR NATURAL WORLD HAS KNOWN IN THE PAST. ONE OF THE EFFECTS COULD BE A GREAT MIGRATION OF ANIMAL AND PLANT LIFE, AND POSSIBLY THE LOSS OF SOME OF THEM ALTOGETHER.

THE CALCULATION HAS BEEN MADE THAT A ONE DEGREE RISE IN TEMPERATURE WOULD OVER TIME LEAD FORESTS TO MOVE 100 KILOMETRES FURTHER NORTH AND SOME ORDINARY FARMING CROPS MAY MOVE AS MUCH AS 200-300 KILOMETRES. Common Ag Policy
JUST IMAGINE THE EFFECTS ON FARMING, ON THE CAP, ON THE SORT OF CROPS YOU CAN GROW IN PARTICULAR AREAS - AND ON NATURE RESERVES. THEY MIGHT FIND THEMSELVES IN THE WRONG PLACES, IF THE FLORA AND FAUNA WHICH THEY ARE MEANT TO PROTECT MIGRATE.

CHANGES IN THE SEA LEVEL AS THE SEA EXPANDS COULD ALSO AFFECT OUR LIVES CONSIDERABLY. AT A COMMONWEALTH HEADS OF GOVERNMENT MEETING A YEAR OR TWO AGO, THE PRESIDENT OF THE MALDIVES REMINDED US THAT NONE OF HIS COUNTRY WAS MORE THAN SIX FEET ABOVE SEA-LEVEL, AND THE CONSEQUENCES OF A SIGNIFICANT OVERALL RISE IN THE SEA-LEVEL COULD BE ONE LESS MEMBER OF THE COMMONWEALTH.

OTHER LOW-LYING COUNTRIES LIKE BANGLADESH WOULD BE BADLY AFFECTED, AND THERE WOULD SURELY BE A GREAT MIGRATION OF POPULATION AWAY FROM AREAS OF THE WORLD LIABLE TO FLOODING, AND FROM AREAS OF DECLINING RAINFALL AND THEREFORE OF SPREADING DESERT. THOSE PEOPLE WILL BE CRYING OUT NOT FOR OIL WELLS BUT FOR WATER.

OF COURSE EVERY DETAIL OF THE FORECASTS MAY NOT BE QUITE RIGHT. IT VERY RARELY IS WHEN YOU ARE TRYING TO PREDICT THE FUTURE. THERE IS STILL A GREAT DEAL OF WORK FOR THE SCIENTISTS TO DO, PARTICULARLY IN TRYING TO ESTIMATE THE DETAILED DISTRIBUTION OF THE EFFECTS OF GLOBAL CLIMATE CHANGE WHICH I HAVE DESCRIBED.

AS THE PANEL'S REPORT ITSELF MAKES CLEAR, WE SHOULD HAVE A BETTER UNDERSTANDING OF MANY OF THESE THINGS IN TEN OR FIFTEEN YEARS' TIME, SAY BY ABOUT THE YEAR 2005. BY THEN WE SHALL HAVE BENEFITED FROM NEW MEASUREMENTS FROM SATELLITES, FROM NEW AND

MORE POWERFUL COMPUTERS AND THE RESULTS OF THE WORK BEING DONE ON OCEAN CIRCULATION.

BUT WE CAN ALREADY DRAW SOME BROAD CONCLUSIONS FROM THE WORK WHICH HAS BEEN DONE.

FIRST, THE CLIMATE CHANGES WHICH WE HAVE WITNESSED IN THE PAST HAVE MAINLY BEEN THE RESULT OF NATURAL FACTORS - CHANGES IN THE EARTH'S ORBIT OR IN THE AMOUNT OF RADIATION GIVEN OFF BY THE SUN FOR INSTANCE. MAN'S ACTIVITIES HAD ONLY A SMALL PART TO PLAY.

IN THE FUTURE, THIS CAN NO LONGER BE ASSUMED. MAN'S ACTIVITIES ARE ALREADY ADDING GREENHOUSE GASES TO THE AIR AT AN UNPRECEDENTED RATE, WITH INEVITABLE CONSEQUENCES FOR OUR FUTURE CLIMATE.

THE ANNUAL ACCUMULATION IN CARBON DIOXIDE REACHING THE ATMOSPHERE IS OF THE ORDER OF 3 BILLION TONNES, AND HALF OF ALL THE CARBON DIOXIDE EMITTED SINCE THE INDUSTRIAL REVOLUTION IS STILL IN THE ATMOSPHERE -AND ALL THIS WHILE WE ARE AT THE SAME TIME DESTROYING TROPICAL FORESTS WHICH ARE A VITAL WAY OF TAKING CARBON DIOXIDE OUT OF THE AIR AND STORING IT.

IT STANDS TO COMMON SENSE THAT THESE FIGURES ARE GOING TO GO UP AS THE WORLD'S POPULATION INCREASES, WITH GREATER INTENSITY OF AGRICULTURE, MORE DESTRUCTION OF FORESTS AND WOODLANDS, AND MORE USE OF FOSSIL FUELS.

WHEN I WAS BORN, THE WORLD'S POPULATION WAS SOME 2 BILLION PEOPLE. MY GRANDSON IS GOING TO GROW UP IN A WORLD OF MORE THAN 6 BILLION PEOPLE, AND THE PREDICTIONS ARE THAT WE SHALL HAVE 10 BILLION PEOPLE BY THE MIDDLE OF THE NEXT CENTURY.

WHICHEVER WAY YOU LOOK AT IT, PROBLEMS ARE BOUND TO ARISE AS A RESULT OF GOING FROM 2 BILLION TO 10 BILLION IN SUCH A SHORT TIME. PUTTING THEM RIGHT WILL BE ALL THE HARDER UNTIL WE SUCCEED IN CURBING THAT RATE OF POPULATION GROWTH.

THE SECOND CONCLUSION THAT CAN ALREADY BE DRAWN IS THAT MORE THAN

ATMOSPHERE INTO SEGMENTS AND SAY: ALL RIGHT, WE'LL LOOK AFTER OUR BIT AND YOU LOOK AFTER YOURS. WE SHALL ONLY BE ABLE TO DEAL WITH THE PROBLEMS BY A GIANT INTERNATIONAL EFFORT, IN WHICH WE ALL CO-OPERATE.

AND THAT LEADS ON TO THE THIRD CONCLUSION: WE WOULD BE TAKING A GREAT RISK WITH FUTURE GENERATIONS IF, HAVING RECEIVED THIS EARLY WARNING, WE DID NOTHING ABOUT IT: OR JUST TOOK THE ATTITUDE "WELL, IT'LL SEE ME OUT".

I REMEMBER SAYING IN MY ROYAL SOCIETY SPEECH THAT WE HAD A FULL REPAIRING LEASE ON THIS EARTH. WITH THE WORK DONE BY THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, WE CAN NOW SAY THAT WE HAVE THE SURVEYOR'S REPORT: AND IT SHOWS THERE ARE FAULTS AND THAT THE REPAIR WORK NEEDS TO START WITHOUT DELAY. THE PROBLEMS DON'T LIE IN THE FUTURE, THEY ARE HERE AND NOW: AND IT IS OUR CHILDREN AND GRANDCHILDREN, WHO ARE ALREADY GROWING UP, WHO WILL BE AFFECTED.

IN SOME AREAS WE HAVE ALREADY STARTED. BRITAIN WAS AMONG THE FIRST TO CALL FOR AN INTERNATIONAL CONVENTION ON CLIMATE.

WE ARE GIVING GENEROUS HELP FOR FORESTRY IN DEVELOPING COUNTRIES.

WE HAVE UNDERTAKEN TO PHASE OUT CFCS AND OTHER OZONE-DEPLETING SUBSTANCES BY THE END OF THE CENTURY. BUT THAT WILL ONLY BE EFFECTIVE IF IT EXTENDS TO DEVELOPING COUNTRIES TOO, AND THEY WILL NEED HELP. WE SHALL HAVE TO ADDRESS THIS ISSUE URGENTLY AT THE LONDON OZONE CONFERENCE NEXT MONTH.

WE MUST ALSO TAKE ACTION ON CARBON DIOXIDE EMISSIONS. THAT WILL MEAN SIGNIFICENT ADJUSTMENTS TO OUR ECONOMIES - MORE EFFICIENT POWER STATIONS, CARS WHICH USE LESS FUEL, BETTER INSULATED HOUSES AND BETTER MANAGEMENT OF ENERGY IN GENERAL. ALL THIS IS BOUND TO TAKE TIME. IT IS NO GOOD SETTING 'POLITICAL' TARGETS FOR ACTION WHICH ARE JUST NOT REALISTIC IN PRACTICE.

ANY TARGET WOULD HAVE TO BE PART OF A WIDE INTERNATIONAL EFFORT,

IN IMPROVING OUR PERFORMANCE, IF OTHERS JUST GO ON AS BEFORE.

BUT PROVIDED OTHERS ARE READY TO TAKE THEIR FULL SHARE, BRITAIN IS PREPARED TO SET ITSELF THE VERY DEMANDING TARGET OF A REDUCTION OF UP TO 30 PER CENT IN PRESENTLY PROJECTED LEVELS OF CARBON DIOXIDE EMISSIONS BY THE YEAR 2005. THIS WOULD MEAN RETURNING EMISSIONS TO THEIR 1990 LEVELS BY THAT DATE. ALL OF THIS WILL BE SPELLED OUT IN OUR WHITE PAPER ON THE ENVIRONMENT WHICH WILL BE PUBLISHED IN THE AUTUMN.

AND MAY I SAY THAT THE PRIVATE SECTOR IS CONSTANTLY SHOWING THE WAY WITH ITS INGENUITY AND INVENTIVENESS. FOR INSTANCE, ICI HAVE DEVELOPED A NEW WAY OF PRODUCING AMMONIA WHICH REDUCES NITROGEN OXIDE EMISSIONS BY 87 PER CENT, SULPHUR DIOXIDE BY 95 PER CENT AND CARBON DIOXIDE BY 60 PER CENT - AND IT USES LESS RESOURCES. THE NET RESULT IS SIGNIFICANTLY LOWER PRODUCTION COSTS AND VERY SUBSTANTIAL ENVIRONMENTAL BENEFITS. INDEED, IF THIS PARTICULAR PROCESS OF PRODUCING AMMONIA WERE ADOPTED WORLD-WIDE, THE SAVINGS IN TERMS OF POLLUTION WOULD BE EQUIVALENT TO TAKING 5 MILLION CARS OFF THE ROAD. IT SHOWS WHAT CAN BE DONE.

THIS IS WHERE THE WORK OF THIS CENTRE WHICH WE ARE OPENING TODAY COMES IN. WITH ITS ADVANCED COMPUTING FACILITIES AND THE SUPERB SKILLS OF ITS SCIENTISTS IT WILL HELP US LOOK INTO THE FUTURE AND PREDICT MORE PRECISELY THE CHANGES IN OUR CLIMATE.

PREVIOUSLY WE COULD GET SOME IDEA OF FUTURE CLIMATES BY OBSERVING AND ANALYSING THE PATTERNS OF THE PAST. BUT THE CHANGES WE CAN EXPECT IN THE FUTURE WILL BE SO MUCH GREATER THAN ANYTHING WE HAVE HITHERTO EXPERIENCED, THAT THESE METHODS WILL NOT BE ADEQUATE AND WE SHALL NEED TO RELY MUCH MORE ON COMPUTER MODELS, WHICH TAKE IN THE FULL COMPLEXITY OF THE CLIMATE SYSTEM.

IT WILL BE ON THE BASIS OF THIS WORK THAT WE SHALL BE ABLE TO ESTABLISH A REALISTIC INTERNATIONAL PROGRAMME OF ACTION AND AN EQUALLY REALISTIC TIME-TABLE. DISCHARGES OF CARBON DIOXIDE AND CFCS, IF UNABATED, WILL GO ON ACCUMULATING IN THE ATMOSPHERE AND CANNOT EASILY BE REVERSED. EVEN THE MOST URGENT MEASURES NOW CANNOT FULLY REPAIR THE DAMAGE OF THE PAST.

BUT ACTION NOW WILL PREVENT THE PROBLEM FROM BECOMING ACUTE AND GIVE US TIME TO IMPROVE OUR PREDICTIONS AND ENLARGE OUR UNDERSTANDING. THE PANEL'S REPORT WILL PRESENT US WITH A VERY FULL AGENDA FOR THE NEXT FIFTEEN YEARS UP TO 2005 AND WE SHOULD START ON IT WITHOUT DELAY.

MAY I WISH THIS HADLEY CENTRE AND ALL WHO WORK HERE EVERY SUCCESS. YOUR TASK IS NO LESS A ONE THAN TO HELP US SAFEGUARD THE FUTURE OF OUR PLANET. MAY WE ALL BE EQUAL TO THAT TASK.

SECTION 1

Greenhouse Gases and Aerosols

3rd Draft
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SECTION 1: GREENHOUSE GASES AND AEROSOLS

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EXECUTIVE SUMMARY

The Earth's climate is dependent upon the radiative balance of the atmosphere, which in turn depends upon the input of solar radiation and the atmospheric abundances of radiatively active trace gases (i.e., greenhouse gases), clouds and aerosols.

Since the industrial revolution the atmospheric concentrations of several greenhouse gases, i.e., carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), nitrous oxide (N_2O), and tropospheric ozone (O_3), have been increasing, primarily due to human activities. Several of these greenhouse gases have long atmospheric lifetimes, decades to centuries, which means that their atmospheric concentrations respond slowly to changes in emission rates. In addition, there is evidence that the concentrations of tropospheric aerosols have increased at least regionally.

Carbon Dioxide: The atmospheric CO_2 concentration, at 353 ppmv in 1990, is now about 25% greater than the pre-industrial (1750-1800) value of about 280 ppmv, and higher than at any time in at least the last 160,000 years. Carbon dioxide is currently rising at about 1.8 ppmv (0.5%) per year due to anthropogenic emissions. Anthropogenic emissions of CO_2 are estimated to be 5.7±0.5 Gt C (in 1987) due to fossil fuel burning, plus 0.6 - 2.5 Gt C (in 1980) due to deforestation. The atmospheric increase during the past decade corresponds to (48±8)% of the total emissions during the same period with the remainder being taken up by the oceans and land. Indirect evidence suggests that the land and oceans sequester CO_2 in roughly equal proportions, though the mechanisms are not all well understood. The time taken for atmospheric CO_2 to adjust to changes in sources or sinks is of order 50-200 years, determined mainly by the slow exchange of carbon between surface waters and deeper layers of the ocean. Consequently, CO_2 emitted into the atmosphere today will influence the atmospheric concentration of CO_2 for centuries into the future. Three models have been used to estimate that even if anthropogenic emissions of CO_2 could be kept constant at present day rates, atmospheric CO_2 would increase to 415 - 480 ppmv by the year 2050, and to 460 - 560 ppmv by the year 2100. In order to stabilize concentrations at present day levels, an immediate reduction in global anthropogenic emissions by 60-80 percent would be necessary.

Methane: Current atmospheric CH_4 concentration, at 1.72 ppmv, is now more than double the pre-industrial (1750-1800) value of about 0.8 ppmv, and is increasing at a rate of about 0.015 ppmv (0.9%) per year. The major sink for CH_4, reaction with hydroxyl (OH) radicals in the troposphere, results in a relatively short atmospheric lifetime of about 10 years. Human activities such as rice cultivation, domestic ruminant rearing, biomass burning, coal mining, and natural gas venting have increased the input of CH_4 into the atmosphere, which combined with an possible decrease in the concentration of tropospheric OH, yields the observed rise in global CH_4. However, the quantitative importance of each of the factors contributing to the observed increase is not well known at present. In order to stabilize concentrations at present day levels, an immediate reduction in global anthropogenic emissions by 15-20 percent would be necessary.

Chlorofluorocarbons: The current atmospheric concentrations of the anthropogenically produced halocarbons, CCl_3F (CFC-11), CCl_2F_2 (CFC-12), $C_2Cl_3F_3$ (CFC-113) and CCl_4 (carbon tetrachloride) are about 280 pptv, 484 pptv, 60 pptv, and 146 pptv, respectively. Over the past few decades their concentrations, except for CCl_4, have increased more rapidly (on a percentage basis) than the other greenhouse gases, currently at rates of at least 4% per year. The fully halogenated CFCs and CCl_4 are primarily removed by photolysis in the stratosphere, and have atmospheric lifetimes in excess of 50 years. Future emissions will, most likely, be eliminated or significantly lower than today's because of current international negotiations to strengthen regulations on chlorofluorocarbons. However, the atmospheric concentrations of CFCs 11, 12 and 113 will still be significant (30 - 40% of current) for at least the next century because of their long atmospheric lifetimes.

Nitrous Oxide: The current atmospheric N_2O concentration, at 310 ppbv, is now about 8% greater than in the pre-industrial era, and is increasing at a rate of about 0.8 ppbv (0.25%) per year. The major sink for N_2O, photolysis in the stratosphere, results in a relatively long atmospheric lifetime of about 150 years. It is difficult to quantitatively account for the source of the current increase in the atmospheric concentration of N_2O but it is thought to be due to human activities. Recent data suggest that the total annual flux of N_2O from combustion and biomass burning is much less than previously believed. Agricultural practices may stimulate emissions of N_2O from soils and play a major role. In order to stabilize concentrations at present day levels, an immediate reduction of 70 - 80% of the additional flux of N_2O that has occurred since the pre-industrial era would be necessary.

Ozone: Ozone is an effective greenhouse gas especially in the middle and upper troposphere and lower stratosphere. Its concentration in the troposphere is highly variable because of its short lifetime. It is photochemically produced in-situ through a series of complex reactions involving carbon monoxide (CO), CH_4, non-methane hydrocarbons (NMHC), and nitrogen oxide radicals (NO_x), and also transported downward from the stratosphere. The limited observational data support positive trends of about 1% per year for O_3 below 8 km in the northern hemisphere (consistent with positive trends in several of the precursor gases, especially NO_x, CH_4, and CO) but probably close to zero trend in the southern hemisphere. There is also evidence that O_3 has decreased by a few percent globally in the lower stratosphere (below 25 km) within the last decade. Unfortunately, there are no reliable long-term data near the tropopause.

Aerosol particles: Aerosol particles have a lifetime of at most a few weeks in the troposphere and occur in highly variable concentrations. A large proportion of the particles that influence cloud processes and the radiative balance is derived from gaseous sulphur emissions. Due to fossil fuel combustion, these emissions have more than doubled globally, causing a large increase in the concentration of aerosol sulphate especially over and around the industrialized regions of Europe and North America. Future concentrations of aerosol sulphate will vary in proportion to changes in anthropogenic emissions. Aerosol particles derived from natural (biological) emissions may contribute to climate feedback processes. During a few years following major volcanic eruptions the concentrations of natural aerosol particles in the stratosphere can be greatly enhanced.

1.1 INTRODUCTION

The Earth's climate is dependent upon the radiative balance of the atmosphere, which in turn depends upon the input of solar radiation and the atmospheric abundances of radiatively active trace gases (i.e., greenhouse gases), clouds and aerosols. Consequently, it is essential to gain an understanding of how each of these climate "forcing agents" varies naturally, and how some of them might be influenced by human activities.

The chemical composition of the Earth's atmosphere is changing, largely due to human activities (Table 1). Air trapped in Antarctic and Greenland ice shows that there have been major increases in the concentrations of radiatively active gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) since the beginning of the industrial revolution. In addition, industrially produced chlorofluorocarbons (CFCs) are now present in the atmosphere in significant concentrations, and there is evidence that the concentrations of tropospheric O_3 and aerosols have increased at least regionally. Atmospheric measurements indicate that in many cases the rates of change have increased in recent decades. Many of the greenhouse gases have long atmospheric life-times, decades to centuries, which implies that their atmospheric concentrations respond slowly to changes in emission rates.

TABLE 1

Summary of Key Greenhouse Gases Influenced by Human Activities [1]

Parameter	CO_2	CH_4	CFC-11	CFC-12	N_2O
Pre-industrial atmospheric concentration (1750-1800)	280 ppmv[2]	0.8 ppmv	0	0	288 ppbv[2]
Current atmospheric concentration (1990)[3]	353 ppmv	1.72 ppmv	280 pptv[2]	484 pptv	310 ppbv
Current rate of annual atmospheric accumulation	1.8 ppmv (0.5%)	0.015 ppmv (0.9%)	9.5 pptv (4%)	17 pptv (4%)	0.8 ppbv (0.25%)
Atmospheric lifetime[4] (years)	(50-200)	10	65	130	150

1 Ozone has not been included in the table because of lack of precise data.

2 ppmv = parts per million by volume;
ppbv = parts per billion by volume;
pptv = parts per trillion by volume.

3 The current (1990) concentrations have been estimated based upon an extrapolation of measurements reported for earlier years, assuming that the recent trends remained approximately constant.

4 For each gas in the table, except CO_2, the "lifetime" is defined here as the ratio of the atmospheric content to the total rate of removal. This time scale also characterizes the rate of adjustment of the atmospheric concentrations if the emission rates are changed abruptly. CO_2 is a special case since it has no real sinks, but is merely circulated between various reservoirs (atmosphere, ocean, biota). The "lifetime" of CO_2 given in the table is a rough indication of the time it would take for the CO_2 concentration to adjust to changes in the emissions (see section 1.2.1 for further details).

The effectiveness of a greenhouse gas in influencing the Earth's radiative budget is dependent upon its atmospheric concentration and its ability to absorb outgoing long-wave terrestrial radiation. Tropospheric water vapour is the single most important greenhouse gas, but its atmospheric concentration is not significantly influenced by direct anthropogenic emissions. Of the greenhouse gases that are affected by human activities, CO_2 has the largest radiative effect, followed by the CFCs, CH_4, tropospheric O_3, and N_2O. Although the present rate of increase in the atmospheric concentration of CO_2 is about a factor of 70,000 times greater than that of CCl_3F (CFC-11) and CCl_2F_2 (CFC-12) combined, and a factor of about 120 times greater than that of CH_4, its contribution to changes in the radiative forcing during the decade of the 1980s was about 55%, compared to 17% for CFCs (11 and 12), and 15% for CH_4 (see Section 2). Other CFCs and N_2O accounted for about 8%, and 5%, respectively, of the changes in the radiative forcing. While the contribution from tropospheric O_3 may be important, it has not been quantified because the observational data is inadequate to determine its trend. This pattern arises because of differences in the efficiencies of the gases to absorb terrestrial radiation.

Aerosol particles play an important role in the climate system because of their direct interaction (absorption and scattering) with solar and terrestrial radiation, as well as through their influence on cloud processes and thereby, indirectly, on radiative fluxes.

There is a clear need to document the historical record of the atmospheric concentrations of greenhouse gases and aerosols, as well as to understand the physical, chemical, geological, biological and social processes responsible for the observed changes. A quantitative understanding of the atmospheric concentrations of these gases requires knowledge of: the cycling and distribution of carbon, nitrogen and other key nutrients within and between the atmosphere, terrestrial ecosystems, oceans and sediments; and the influence of human actions on these cycles. Without knowledge of the processes responsible for the observed past and present changes in the atmospheric concentrations of greenhouse gases and aerosols it will not be possible to predict with confidence future changes in atmospheric composition, nor therefore the resulting changes in the radiative forcing of the atmosphere.

1.2 CARBON DIOXIDE

1.2.1 The Cycle of Carbon in Nature

Carbon in the form of CO_2, carbonates, organic compounds, etc. is cycled between various reservoirs, atmosphere, oceans, land biota and marine biota, and on geological time scales, also sediments and rocks (Figure 1.1; for more detailed reviews see Sundquist,1985: Bolin, 1981, 1986; Trabalka, 1985; Siegenthaler, 1986). The largest natural exchange fluxes occur between the atmosphere and the terrestrial biota and between the atmosphere and the surface water of the oceans. By comparison, the net inputs into the atmosphere from fossil fuel combustion and deforestation are much smaller, but are large enough to modify the natural balance.

The turnover time of CO_2 in the atmosphere, measured as the ratio of the content to the fluxes through it, is about 4 years. This means that on average it takes only a few years before a CO_2 molecule in the atmosphere is taken up by plants or dissolved in the ocean. This short time scale must not be confused with the time it takes for the atmospheric CO_2 level to adjust to a new equilibrium if sources or sinks change. This adjustment time, corresponding to the lifetime in Table 1, is of the order of 50 - 200 years, determined mainly by the slow exchange of carbon between surface waters and the deep ocean. The adjustment time is important for the discussions on global warming potential, cf. Section 2.2.7.

Because of its complex cycle, the decay of excess CO_2 in the atmosphere does not follow a simple exponential curve, and therefore a single time scale cannot be given to characterize the whole adjustment process toward a new equilibrium. The two curves in Figure 1.2, which represent simulations of a pulsed input of CO_2 into the atmosphere using atmosphere-ocean models (one box model and one General Circulation Model (GCM)), clearly show that the

initial response (governed mainly by the uptake of CO_2 by ocean surface waters) is much more rapid than the later response (influenced by the slow exchange between surface waters and deeper layers of the oceans). For example, the first reduction by 50 percent occurs within some 50 years, whereas the reduction by another 50 percent (to 25 percent of the initial value) requires approximately another 200 years. The concentration will actually never return to its original value, but reach a new equilibrium level; about 15 percent of the total amount of CO_2 emitted will remain in the atmosphere.

1.2.1.1 The role of the atmosphere

The mean annual concentration of CO_2 is relatively homogeneous throughout the troposphere because the troposphere is mixed on a time scale of about 1 year. The pre-industrial atmospheric CO_2 concentration was about 280 ppmv, as reconstructed from ice core analyses (c.f. Section 1.2.4.1), corresponding to an atmospheric amount of 594 Gigatonnes of carbon (GtC: 1 Gt = 10^9t = 10^{15}g; 1 ppmv CO_2 of the global atmosphere equals 2.12 GtC and 7.8 Gt CO_2); today, the level is about 353 ppmv (Figures 1.3 and 1.4). The atmospheric increase has been monitored since 1958 at a growing number of stations (Keeling and Heimann, 1986; Keeling et al., 1989a; Beardsmore and Pearman, 1987; Conway et al., 1988).

1.2.1.2 The role of the ocean

On time scales of decades or more, the CO_2 concentration of the unperturbed atmosphere is mainly controlled by the exchange with the oceans, since this is the largest of the carbon reservoirs. There is a continuous exchange of CO_2 in both directions between the atmosphere and oceans. The net flux into (or out of) the ocean is driven by the difference between the atmospheric partial pressure of CO_2 and the equilibrium partial pressure of CO_2 (pCO_2) in surface waters.

The exchange of carbon between the surface and deeper layers is accomplished mainly through transport by water motions. Ventilation of the thermocline (approximately the uppermost km of the ocean) is particularly important for the downward transport of anthropogenic CO_2. The deep circulation is effective on time scales of 100-1000 years.

The natural carbon cycle in the ocean and in particular pCO_2 in surface ocean water are strongly influenced also by biological processes. The marine biota serve as a "biological pump", transporting organic carbon from surface waters to deeper layers as a rain of detritus at a rate of about 4 GtC per year (Eppley and Peterson, 1979), which is balanced by an equal upward transport of carbon by deeper water richer in CO_2 than surface water. This "biological pump" has the effect of reducing surface pCO_2 very substantially: without the biological pump ("dead ocean") the pre-industrial CO_2 level would have been higher than the observed value of 280 ppmv, at perhaps 450 ppmv (Wenk, 1985; Bacastow and Maier-Reimer, 1990). Alterations in the marine biota due to climatic change could therefore have a substantial effect on CO_2 levels in the future. Note, however, that the "biological pump" does not help to sequester anthropogenic CO_2 (see Section 1.2.4.2).

1.2.1.3 The role of terrestrial vegetation and soils

The most important processes in the exchange of carbon are those of photosynthesis, autotrophic respiration (i.e., CO_2 production by the plants) and heterotrophic (i.e., essentially microbial) respiration converting the organic material back into CO_2 mainly in soils (c.f. Section 10 for a detailed discussion). Net primary production (NPP) is the net annual uptake of CO_2 by the vegetation; NPP is equal to the gross uptake (gross primary production, GPP) minus autotrophic respiration. In an unperturbed world, NPP and decomposition by heterotrophic respiration are approximately balanced on an annual basis; formation of soils and peat corresponds to a (relatively small) excess of NPP.

The carbon balance can be changed considerably by the direct impact of man (land use changes, particularly deforestation), by climate changes, and by other changes in the environment, e.g., atmospheric composition. Since the pools and fluxes are large (NPP 50-60 GtC per year, GPP 90-120 GtC per year; Houghton et al, 1985b), any perturbations can have a significant effect on the atmospheric concentration of CO_2.

1.2.2 Anthropogenic Perturbations

The concentrations of CO_2 in the atmosphere are primarily affected by two anthropogenic processes: release of CO_2 from fossil fuel combustion, and changes in land use such as deforestation.

1.2.2.1 Historical fossil fuel input

The global input of CO_2 to the atmosphere from fossil fuel combustion, plus minor industrial sources like cement production, has shown an exponential increase since 1860 (about 4% per year), with major interruptions during the two world wars and the economic crisis in the thirties (Figure 1.5). Following the "oil crisis" of 1973, the rate of increase of the CO_2 emissions first decreased to approximately 2% per year, and after 1979 the global emissions remained almost constant at a level of 5.3 GtC per year until 1985, when they started to rise again, reaching 5.7 GtC per year in 1987 (Figure 1.5). The cumulative release of CO_2 from fossil fuel use and cement manufacturing from 1850 to 1987 is estimated at 200 GtC ± 10% (Marland, 1989).

Ninety five percent of the industrial CO_2 emissions are from the northern hemisphere, dominated by industrial countries, where annual releases reach up to about 5 tC per capita (Rotty and Marland, 1986). In contrast, CO_2 emission rates in most developing countries lie between 0.2 and 0.6 tC per capita per year. However, the relative rate of increase of the CO_2 emissions is much larger in the developing countries (ca 6% per year), showing almost no slowing down after 1973 in contrast to Western Europe and North America where the rate of increase decreased from about 3% per year (1945-72) to less than 1% per year (1973-84).

1.2.2.2 Historical land use changes

The vegetation and soils of unmanaged forests hold 20 to 100 times more carbon per unit area than agricultural systems. The amount of carbon released to the atmosphere compared to that accumulated on land as a result of land use change depends on the amounts of carbon held in biomass and soils, rates of oxidation of wood products (either rapidly through burning or more slowly through decay), rates of decay of organic matter in soils, and rates of regrowth of forests following harvest or abandonment of agricultural land. The heterogeneity of terrestrial ecosystems makes estimation of global inventories and fluxes difficult.

The total release of carbon to the atmosphere from changes in land use, primarily deforestation, between 1850 and 1985 has been estimated to be about 115 GtC (Houghton and Skole, 1990), with an error limit of about ±35 GtC. The components of the flux to the atmosphere are: (1) burning associated with land use change; (2) decay of biomass on site (roots, stumps, slash, twigs etc.); (3) oxidation of wood products removed from site (paper, lumber, waste etc.); (4) oxidation of soil carbon; minus (5) regrowth of trees and redevelopment of soil organic matter following harvest. Although the greatest releases of carbon in the nineteenth and early twentieth centuries were from lands in the temperate zone (maximum 0.5 GtC per year), the major source of carbon during the past several decades has been from deforestation in the tropics, with a significant increase occurring since 1950. Over the entire 135 yr period, the release from tropical regions is estimated to have been 2-3 times greater than the release from middle and high latitudes. Estimates of the flux in 1980 range from 0.6 to 2.5 GtC (Houghton et al. 1985a, 1987, 1988; Detwiler and Hall, 1988): virtually all of this flux is from the tropics. The few regions for which data exist suggest that the annual flux is higher now than it was in 1980.

1.2.3 Long-Term Atmospheric Carbon Dioxide Variations

The most reliable information on past atmospheric CO_2 concentrations is obtained by the analysis of polar ice cores. The process of air occlusion lasts from about 10 up to 1000 years, depending on local conditions (e.g., precipitation rate), so that an air sample in old ice reflects the atmospheric composition averaged over a corresponding time interval.

Measurements on samples representing the last glacial maximum (18,000 yr before present) from ice cores from Greenland and Antarctica (Neftel et al, 1982, 1988; Delmas et al., 1980) showed CO_2 concentrations of 180-200 ppmv, i.e., about 70 percent of the pre-industrial value. Analyses on the ice cores from Vostok, Antarctica, have provided new data on natural variations of CO_2, covering a full glacial-interglacial cycle (Figure 1.6; Barnola et al., 1987). Over the whole period there is a remarkable correlation between polar temperature, as deduced from deuterium data, and the CO_2 profile. The glacial-interglacial shifts of CO_2 concentrations must have been linked to large-scale changes in the circulation of the ocean, and in the whole interplay of biological, chemical and physical processes, but the detailed mechanisms are not yet very clear. The CO_2 variations were large enough to potentially contribute, via the greenhouse effect, to a substantial (although not the major) part of the glacial-interglacial climate change (Hansen et al., 1984; Broccoli and Manabe, 1987).

Ice core studies on Greenland ice indicate that during the last glaciation, CO_2 concentration shifts of the order of 50 ppmv may have occurred within less than 100 years (Stauffer et al., 1984), parallel to abrupt, drastic climatic events (temperature changes of the order of 5°C). These rapid CO_2 changes have not yet been identified in ice cores from Antarctica (possibly due to long occlusion times; Neftel et al., 1988), therefore, it is not yet clear if they are real or represent artefacts in the ice record.

1.2.4 The Contemporary Record of Carbon Dioxide - Observations and Interpretation

1.2.4.1 The carbon dioxide increase from pre-industrial period

Relatively detailed CO_2 data have been obtained for the last millennium from Antarctic ice cores (Neftel et al, 1985a; Friedli et al, 1986; Siegenthaler et al., 1988; Raynaud and Barnola, 1985, Pearman et al., 1986). They indicate that during the period 1000 to 1800, the atmospheric concentration was between 270 and 290 ppmv. The relative constancy seems surprising in view of the fact that the atmosphere exchanges about 30 percent of its CO_2 with the oceans and biota each year . This indicates that the sensitivity of atmospheric CO_2 levels to minor climatic changes such as the Little Ice Age (lasting from the end of the 16th to the middle of the 19th century), where global mean temperatures probably decreased by about 1°C, is small.

A precise reconstruction of the CO_2 increase during the past two centuries has been obtained from an ice core from Siple Station, Antarctica (Figure 1.3; Neftel et al., 1985a, Friedli et al., 1986). These results indicate that CO_2 started to rise around 1800 and had already increased by about 15 ppmv by 1900. Precise direct atmospheric measurements started in 1958, when the level was about 315 ppmv and the rate of increase 0.6 ppmv per year. The present atmospheric CO_2 level has reached 353 ppmv, and the mean growth rate has now reached about 1.8 ppmv per year (Figure 1.4; Keeling et al, 1989a).

1.2.4.2 Uptake by the ocean

The ocean is an important reservoir for taking up anthropogenic CO_2. The relative increase of dissolved inorganic carbon (total CO_2) in ocean water is smaller than in the atmosphere (only 2-3 percent until now, see below). Precise measurements of dissolved inorganic carbon can be made with present analytical tools. However, an accurate determination of the trend in dissolved inorganic carbon is difficult because of its variability in time and space. Hence, repeated transects and time series will be required to assess the total oceanic CO_2 uptake with good precision.

The net flux of CO_2 into (or out of) the ocean is given by the product of a gas transfer coefficient and ΔpCO_2 (the CO_2 partial pressure difference between ocean and atmosphere). The gas transfer coefficient increases with increasing wind speed and also depends on water temperature. Therefore, the net flux into the ocean can be estimated from a knowledge of the atmospheric CO_2 concentration, pCO_2 in surface water (for which the data are still sparse), the global distribution of wind speeds over the ocean as well as the relation between wind speed and gas transfer coefficient (which is known to ±30% only). There have been several

estimates of the global net uptake of CO_2 by the oceans using observations (e.g., Enting and Pearman, 1982, 1987). The most recent estimate yields 1.6 GtC per year (Tans et al., 1990); the error of this estimate is, according to the authors, not easy to estimate.

Estimates of oceanic CO_2 uptake, in the past and in the future, require models of the global carbon cycle that take into account air-sea gas exchange, aqueous carbonate chemistry and the transport from the surface to deep ocean layers. The aqueous carbonate chemistry in sea water operates in a mode that if the atmospheric CO_2 concentration increases by e.g., 10%, then the concentration of dissolved inorganic carbon in sea water increases by only about 1% at equilibrium. Therefore, the ocean is not such a powerful sink for anthropogenic CO_2 as might seem first when comparing the relative sizes of the reservoirs (Figure 1.1).

The rate at which anthropogenic CO_2 is transported from the surface to deeper ocean layers is determined by the rate of water exchange in the vertical. It is known from measurements of the radioactive isotope ^{14}C that on average it takes hundreds to about one thousand years for water at the surface to penetrate to well below the mixed layer of the major oceans (e.g., Broecker and Peng, 1982). Thus, in most oceanic regions only the top several hundred metres of the oceans have at present taken up significant amounts of anthropogenic CO_2. An exception is the North Atlantic Ocean where bomb-produced tritium has been observed even near the bottom of the sea, indicating the active formation of new deep water.

The rain of biogenic detrital particles, which is important for the natural carbon cycle, does not significantly contribute to a sequestering of excess CO_2, since the marine biota do not directly respond to the CO_2 increase. Their activity is controlled by other factors, such as light, temperature and limiting nutrients (e.g., nitrogen, phosphorus, silicon). Thus, only the input of fertilizers (phosphate, nitrate) into the ocean through human activities may lead to an additional sedimentation of organic carbon in the ocean; different authors have estimated the size of this additional sink between 0.04 and 0.3 GtC per year (see Baes, 1985). It seems thus justified to estimate the fossil fuel CO_2 uptake to date considering the biological flux to be constant, as long as climatic changes due to increasing greenhouse gases, or natural causes, do not modify the marine biotic processes. Although this appears a reasonable assumption for the past and present situation, it may well not be so in the future.

The carbon cycle models used to date to simulate the atmosphere-ocean system have often been highly simplified, consisting of a few well-mixed or diffusive reservoirs (boxes) (e.g., Oeschger et al. 1975: Broecker et al., 1980, Bolin, 1981, Enting and Pearman, 1987; Siegenthaler, 1983). Even though these box models are highly simplified they are a powerful means for identifying the importance of the different processes that determine the flux of CO_2 into the ocean (e.g., Broecker and Peng, 1982; Peng and Broecker, 1985). The results of these models are considered to be reasonable because, as long as the ocean circulation is not changing, the models need only simulate the transport of excess CO_2 from the atmosphere into the ocean, but not the actual dynamics of the ocean. In the simple models, the oceanic transport mechanisms, eg., formation of deep water, are parameterized. The transport parameters (e.g., eddy diffusivity) are determined from observations of transient tracers that are analogs to the flux of anthropogenic CO_2 into the ocean. If a model reproduces correctly the observed distribution of, e.g., bomb-produced ^{14}C, then it might be expected to simulate reasonably the flux of CO_2 into the ocean. A 1-D box-diffusion model yields an oceanic uptake of 2.4 GtC per year on average for the decade 1980 - 1989, and an outcrop-diffusion model (both described by Siegenthaler, 1983) 3.6 GtC per year. The latter model most probably overpredicts the flux into the ocean, because it includes an infinitely fast exchange between high-latitude surface waters and the deep ocean.

However, it is obviously desirable to use 3-dimensional (3-D) general circulation models of the oceans for this purpose. At this time, only a few modeling groups have started to do this. One 3-D model (Maier-Reimer and Hasselmann, 1987) gives a similar CO_2 uptake as a 1-D box-diffusion model of Siegenthaler (1983), as illustrated by the model response to a pulse input of CO_2 (Figure 1.2). In a recent revised version of this model (Maier-Reimer et al., personal communication) the ocean takes up less CO_2, about 1.2 GtC per year on average for the decade 1980 - 1989. The GFDL 3-D ocean model (Sarmiento et al, 1990) has an oceanic uptake of

1.9 GtC per year for the same period. 3-D ocean models and especially coupled atmosphere-ocean models are the only means to study in a realistic way the feedback effects that climate change may have on atmospheric CO_2 via alteration of the ocean circulation (cf. Section 1.2.7.1). However, models need to be constrained by more data than are presently available.

The oceanic uptake of CO_2 for the decade 1980 - 1989, as estimated based on carbon models (e.g., Siegenthaler and Oeschger, 1987; Maier-Reimer et al., personal communication, 1990; Goudriaan, 1989; Sarmiento et al., 1990) is in the range 2.0±0.8 GtC per year.

1.2.4.3 Redistribution of anthropogenic carbon dioxide

During the period 1850 to 1986, 195±20 GtC were released by fossil fuel burning and 117±35 GtC by deforestation and changes in land use, adding up to a cumulative input of 312±40 GtC.

Atmospheric CO_2 increased from about 288 ppmv to 348 ppmv during this period, corresponding to (41±6)% of the cumulative input. This percentage is sometimes called the "airborne fraction", but that term should not be misunderstood: all CO_2, anthropogenic and non-anthropogenic, is continuously being exchanged between atmosphere, ocean and biosphere. Conventionally, an "airborne fraction" referring to the fossil input only has often been quoted, because only the emissions due to fossil fuel burning are known with good precision. However, this may be misleading, since the atmospheric increase is a response to the total emissions. We therefore prefer the definition based on the latter. The airborne fraction for the period 1980 - 1989 (see calculation below) corresponds to (48±8)% of the cumulative input.

In model simulations of the past CO_2 increase, using estimated emissions from fossil fuels and deforestation, it has generally been found that the simulated increase is larger than that actually observed. An estimate for the decade 1980-1989 is:

Emissions from fossil fuels into the atmosphere (Figure 1.5)	5.4±0.5 GtC per yr
Emissions from deforestation and land use	1.6±1.0
Accumulation in the atmosphere	3.4±0.2
Uptake by the ocean	2.0±0.8
Net imbalance	1.6±1.4

The result from this budget and from other studies is that the estimated emissions exceed the sum of atmospheric increase plus model-calculated oceanic uptake by a significant amount. The question therefore arises whether an important mechanism has been overlooked. All attempts to identify such a "missing sink" in the ocean have, however, failed so far. A possible exception is that a natural fluctuation in the oceanic carbon system could have caused a decreasing atmospheric baseline concentration in the past few decades; this does not appear likely in view of the relative constancy of the pre-industrial CO_2 concentration. There are possible processes on land, which could account for the missing CO_2 (but it has not been possible to verify them). They include the stimulation of vegetative growth by increasing CO_2 levels (the CO_2 fertilization effect), the possible enhanced productivity of vegetation under warmer conditions, and the direct effect of fertilization from agricultural fertilizers and from nitrogenous releases into the atmosphere. It has been estimated that increased fertilization by nitrogenous releases could account for a sequestering of up to a maximum of 1 GtC per year in terrestrial ecosystems (Melillo, private communication, 1990). In addition, changed forest management practices may also result in an increase in the amount of carbon stored in northern mid-latitude forests. The extent to which mid-latitude terrestrial systems can sequester carbon before becoming saturated and ineffective is unknown. As mid-latitude terrestrial systems become close to becoming saturated, and hence ineffective in sequestering carbon, this would allow more of the CO_2 to remain in the atmosphere.

A technique for establishing the global distribution of surface sources and sinks has been to take global observations of atmospheric CO_2 concentration and isotopic composition and to invert these by means of atmospheric transport models to deduce spatial and temporal patterns of surface fluxes (Pearman et al., 1983; Pearman and Hyson, 1986; Keeling and Heimann,

1986). The observed interhemispheric CO_2 concentration difference (currently about 3 ppmv) is smaller than one would expect given that nearly all fossil releases occur in the northern hemisphere. The results of this approach suggest that there is an unexpectedly large sink in the northern hemisphere, equivalent to more than half of the fossil fuel CO_2 release (Enting and Mansbridge, 1989; Tans et al., 1990; Keeling et al., 1989b). Furthermore, it has been concluded that the oceanic uptake compatible with oceanic and atmospheric CO_2 data and with a 3-dimensional atmospheric transport model is at most 1 GtC per year (Tans et al., 1990). Thus, a significant terrestrial sink, possibly larger than the oceanic uptake, is suggested by these model analyses.

1.2.4.4 Seasonal variations

Atmospheric CO_2 exhibits a seasonal cycle, dominated by the seasonal uptake and release of atmospheric CO_2 by land plants. Its amplitude is small (1.2 ppmv peak-to-peak) in the southern hemisphere and increases northward to a maximum of order 15 ppmv peak-to-peak in the boreal forest zone (55-65° N).

The amplitude of the seasonal cycle has been observed to be increasing (e.g., Pearman and Hyson, 1981: Bacastow et al., 1985; Thompson et al., 1986). For example, at Mauna Loa, Hawaii, the seasonal amplitude has increased by nearly 20% since 1958. The increase has however, not been monotonic, and different evaluation methods yield somewhat different values; still, it is statistically significant. This increasing amplitude could point to a growing productivity (NPP) of the terrestrial ecosystems, and to a sequestering of carbon by a growing biomass, provided the increase in biomass is not fully compensated by respiration. It is important to note that such a change does not necessarily indicate increased productivity or increased storage of carbon (Pearman and Hyson, 1981; Kohlmaier et al., 1989; Houghton, 1987); it could also be due to, e.g., accelerated soil respiration in winter.

1.2.4.5 Interannual variations

Small imbalances in natural exchange fluxes are reflected in interannual CO_2 concentration fluctuations (±1 ppmv over 1-2 years). They are correlated with the El Niño-Southern Oscillation (ENSO) phenomenon (Thompson et al., 1986; Keeling et al., 1989a), which suggests a relation to changes in the equatorial Pacific Ocean, where normally the upwelling causes a high pCO_2 peak and outgassing of CO_2 into the atmosphere. However, a closer inspection shows that this cannot be the dominating mechanism, since during El Niño, the equatorial pCO_2 peak disappears (Feely et al., 1987), while atmospheric CO_2 grows more strongly than normally. Alternatively, processes in the land biosphere, perhaps in response to climatic events connected with ENSO events, may be responsible. This explanation is supported by one set of stable carbon isotope data on atmospheric CO_2 (Keeling et al., 1989a); but not supported by a second set (Goodman and Francey, 1988).

1.2.4.6 Temporal variations of carbon isotopes

The release of CO_2 from biospheric carbon and fossil fuels, both having lower $^{13}C/^{12}C$ ratios than atmospheric CO_2, has led to a decrease of the isotope ratio $^{13}C/^{12}C$ in the atmosphere by about 1‰. The man-made emissions of ^{14}C-free fossil fuel CO_2 have likewise caused a decrease of the atmospheric ^{14}C concentration (measured on tree-rings) of the order of 2% from 1800 to 1950. Both isotopic perturbations can be used to constrain the history of the anthropogenic release of CO_2. The observed decreases of ^{13}C, as observed in air trapped in ice cores (Friedli et al., 1986) and ^{14}C, observed in tree rings, agree, within experimental uncertainty, with those expected from model calculations with the same carbon cycle models as used for studying the CO_2 increase (Stuiver and Quay, 1981; Siegenthaler and Oeschger, 1987). The interpretation of ^{13}C trends in tree rings has proven to be difficult because of plant physiological effects on isotope fractionation (Francey and Farquhar, 1982).

1.2.5 Evidence that the Contemporary Carbon Dioxide Increase is Anthropogenic

How do we know that in fact human activity has been responsible for the well documented 25% increase in atmospheric CO_2 since the early 19th century? Couldn't this rise instead be the result of some long-term natural fluctuation in the natural carbon cycle? Simple arguments allow us to dismiss this possibility.

First, the observational CO_2 records from ice cores with good time resolution clearly show that the maximum range of natural variability about the mean of 280 ppmv during the past 1000 years was small (10 ppmv over a 100 year timescale), that is an order of magnitude less than the observed rise over the last 150 years. A value as high as the current level of 353 ppmv is not observed anywhere in the measured ice core record for the atmospheric history during the past 160,000 years; the maximum value is 300 ppmv during the previous interglacial, 120,000 years ago.

Second, the observed rate of CO_2 increase closely parallels the accumulated emission trends from fossil fuel combustion and from land use changes (c.f. Section 1.2.2). Since the start of atmospheric monitoring in 1958, the annual atmospheric increase has been smaller each year than the fossil CO_2 input. Thus, oceans and biota together must have been a global sink rather than a source during all these years. Further evidence is provided by the fact that the north-to-south CO_2 concentration difference has been observed to increase from 1 ppmv in 1960 to 3 ppmv in 1985, parallel to the growth of the (northern hemisphere) fossil fuel combustion sources (Keeling et al., 1989a).

Third, the observed isotopic trends of ^{13}C and ^{14}C agree qualitatively with those expected due to the CO_2 emissions from fossil fuels and the biosphere, and they are quantitatively consistent with results from carbon cycle modelling.

1.2.6 Sensitivity Analyses for Future Carbon Dioxide Concentrations

Future atmospheric CO_2 concentrations depend primarily on emission rates from energy use and deforestation, and on the effectiveness of the ocean and land biota as CO_2 sinks. For the sake of illustration, several schematic scenarios are shown in Figures 1.7 and 1.8. Those of Figure 1.7 are based on prescribed total CO_2 emission rates after 1990, for those in Figure 1.8 atmospheric concentrations after 1990 were prescribed and the corresponding emission rates were calculated to fit these concentrations. A box-diffusion model of the global cycle was used for these simulations (Enting and Pearman, 1982, 1987), with an oceanic eddy diffusivity of 5350 $m^2 year^{-1}$ and an air-sea gas exchange rate corresponding to an exchange coefficient of 0.12 $year^{-1}$. The calculations assume no biospheric-climate feedbacks, and also assume that after 1990 the net biospheric input of CO_2 is zero, i.e., the input of CO_2 from tropical deforestation is balanced by uptake of CO_2 by terrestrial ecosystems.

In case a (all emissions stopped; Figure 1.7), the atmospheric concentration declines, but only slowly (from 351 ppmv in 1990 to 331 ppmv in 2050 and 324 ppmv in 2100), because the penetration of man-made CO_2 to deeper ocean layers takes a long time. Even if the emissions were reduced by 2% per year from 1990 on (case b), atmospheric CO_2 would continue to increase for several decades. Case c (constant emission rate after 1990) gives CO_2 levels of about 450 ppmv in 2050 and 520 ppmv in 2100. A constant relative growth rate of 2% per year (case d) would yield 575 ppmv in 2050 and 1330 ppmv in 2100. Comparison of cases b, c and d clearly shows that measures to reduce emissions will result in slowing down the rate of atmospheric CO_2 growth.

Cases b' and c', in comparison to b and c, schematically illustrate the effect of reducing emissions in 2010 instead of in 1990.

If an (arbitrary) threshold of 420 ppmv. i.e., 50% above pre-industrial, is not to be exceeded (case e , Figure 1.8), then CO_2 production rates should slowly decline, reaching about 50% of their present value by 2050 and 30% by 2100. In order to keep the concentration at the present

level (case f), emissions would have to be reduced drastically to 30% of present immediately and to less than 20% by 2050.

The results of scenario calculations with a 3-D ocean-atmosphere model (Maier-Reimer and Hasselmann, 1987; Maier-Reimer et al., personal communication, 1990--revised model) give higher concentrations than those obtained with a box-diffusion model shown in Figure 1.7. For instance, about 480 ppmv in the year 2050 and about 560 ppmv in the year 2100 for scenario c, compared to about 450 ppmv and 520 ppmv in Figure 1.7. On the other hand, calculations with a box model that includes a biospheric CO_2 sink (Goudriaan, 1989) yields somewhat lower concentrations than shown in Figure 1.7, for instance about 415 ppmv in the year 2050 and 460 ppmv in the year 2100 for scenario c.

1.2.7 Feedbacks from Climate Change into the Carbon Dioxide Cycle

As increasing greenhouse gas concentrations alter the Earth's climate, changing climate and environmental conditions in their turn act back on the carbon cycle and atmospheric CO_2. The climate change Earth has experienced in the recent past is still within the range of natural short-term variability, and so are probably, therefore, the feedback effects of anthropogenic climate change. However, as the changes in the climate become larger than natural climatic variation the magnitude of the feedback effects should begin to have a significant effect. These feedbacks could in general be either positive (amplifying the initial changes) or negative (attenuating them).

1.2.7.1 Oceanic feedback effects

The following are possible feedback effects on the ocean-atmosphere carbon system:

1.2.7.1.1 Ocean temperature: Ocean temperature changes can affect sea water CO_2 chemistry. Surface-water pCO_2 will increase with increasing temperature, tending to decrease the net uptake by the oceans. The future atmospheric CO_2 increase may be amplified by something like 5 percent due to this effect (Lashof, 1989).

1.2.7.1.2 Ocean circulation: The ocean circulation may change in response to climatic change. As a consequence of increasing surface water temperatures, the thermocline may become more resistant to vertical mixing and slow down the uptake of anthropogenic CO_2. Modified wind stress may affect ocean circulation. However, the overall change in ocean dynamics, and consequently in CO_2 uptake, due to a climatic change cannot be estimated from simple considerations; a proper evaluation of such an effect can only be done using dynamical ocean models. Studies on Greenland ice cores indicates that during the last glaciation, significant CO_2 concentration shifts may have occurred within less than 100 years (c.f. Section 1.2.3), probably caused by strong changes of large-scale ocean circulation. Therefore, the possibility that, due to climatic changes, unexpected abrupt events may take place in the natural carbon system cannot be excluded.

1.2.7.1.3 Gas exchange rates: A change in the global wind pattern could influence the gas transfer from the atmosphere to the sea surface. Carbon cycle models show that the net CO_2 uptake by the global ocean is not sensitive to the gas transfer coefficients (because it is controlled mainly by vertical mixing, not by gas exchange; Oeschger et al., 1975; Broecker et al., 1980; Sarmiento et al., 1990), so this effect would probably be of minor influence.

1.2.7.1.4 Modification of oceanic biogeochemical cycling: The rain of dead organic particles corresponds to a continuous export flux of carbon (and nutrients) out of the ocean surface, which under non-perturbed conditions is balanced by an equal upward transport of dissolved carbon (and dissolved nutrients) by water motion. In polar regions and strong upwelling zones, where productivity is not limited by nitrogen or phosphorus, the balance could become disturbed consequent on variations in ocean dynamics (c.f. Section 1.2.7.1.2), so as to influence atmospheric CO_2. As a result of climate change, the distribution of marine ecosystems and species composition could change, which could affect pCO_2 in surface waters. It is not possible at present to predict the direction and magnitude of such effects.

Warming of the oceans might lead to accelerated decomposition of dissolved organic carbon, converting it into CO_2, and thus amplify the atmospheric increase (Brewer, personal communication, 1990).

1.2.7.1.5 UV-B radiation: A reduction in stratospheric O_3 would increase the intensity of UV-B radiation at the Earth's surface. This might have negative effects on the marine biota due to a decrease of marine productivity and thus on the biological carbon pump. This could lead to an increase in the concentration of CO_2 in surface waters and consequently in the atmosphere.

1.2.7.2 Terrestrial biospheric feedbacks

The following are probable feedback effects on the terrestrial biosphere-atmospheric carbon system:

1.2.7.2.1 Carbon dioxide fertilization: Short-term experiments under controlled conditions with crops and other annuals, as well as with few perennials, show an increase in the rates of photosynthesis and growth in most plants under elevated levels of CO_2 (Strain and Cure, 1985). If elevated levels of CO_2 increase the productivity of natural ecosystems, more carbon may be stored in woody tissue or soil organic matter. Such a storage of carbon will withdraw carbon from the atmosphere and serve as a negative feedback on the CO_2 increase. Of particular importance is the response of forests (Luxmoore et al., 1986), given that forests conduct about 2/3 of global photosynthesis (50% of this cycles annually through leaves, while 50% is stored in woody tissue). However, it is not clear whether the increases in photosynthesis and growth will persist for more than a few growing seasons, whether they will occur at all in natural ecosystems and to what degree they will result in an increased storage of carbon in terrestrial ecosystems.

1.2.7.2.2 Eutrophication and toxification: The increased availability of nutrients such as nitrate and phosphate from agricultural fertilizers and from combustion of fossil fuel may stimulate the growth of plants. It has been estimated that the effect of eutrophication, both on land and in the oceans, could be as large as 1 GtC per year (Melillo, private communication, 1990). However, it should be noted that the greater availability of nutrients has often been associated with increasing levels of acid precipitation and air pollution, which have been associated with a reduction in the growth of terrestrial biota.

1.2.7.2.3 Temperature: Under non-tropical conditions, photosynthesis and respiration by plants and by microbes both tend to increase with increasing temperature; but respiration is the more sensitive process, so that a warming of global air temperature is likely to result in an initially increased release of carbon to the atmosphere. Estimates indicate that the additional flux might be significant, perhaps as large as one or a few GtC per year (Woodwell, 1983; Kohlmaier, 1988; Lashof, 1989; Houghton and Woodwell, 1989). This temperature-enhanced respiration would be a positive feedback on global warming.

1.2.7.2.4 Water: Changes in soil water may affect carbon fixation and storage. Increased moisture can be expected to stimulate plant growth in dry ecosystems and to increase the storage of carbon in tundra peat. There is a possibility that stresses brought about by climatic change may be alleviated by increased levels of atmospheric CO_2. At present however, it is not possible to predict reliably either the geographical distribution of changes in soil water or the net effect of these changes on carbon fluxes and storage in different ecosystems. Changes in climate are generally believed to be more important than changes in the atmospheric concentration of CO_2 in affecting ecosystem processes (c.f. Section 10.)

1.2.7.2.5 Change in geographical distribution of vegetation types: In response to environmental change, structure and location of vegetation types may change. If the rate of change is slow, plant distributions may adjust. If, however, the rate of change is fast, large areas of forests might not be able to adapt rapidly enough, hence be negatively affected with a subsequent release of CO_2 to the atmosphere.

1.2.7.2.6 UV-B radiation: A reduction in stratospheric O_3 would increase the intensity of UV-B radiation at the Earth's surface. Increased UV-B may have a detrimental effect on many land biota, including crops (Teramura, 1983), thus affecting the strength of the biospheric sink of CO_2 over land.

1.2.8 Conclusions

The atmospheric CO_2 concentration is now about 353ppmv, 25% higher than the pre-industrial (1750-1800) value and higher than at any time in at least the last 160,000 years. This rise, currently amounting to about 1.8 ppmv per year, is beyond any doubt due to human activities. Anthropogenic emissions of CO_2 were 5.7±0.5 GtC due to fossil fuel burning in 1987, plus 0.6 to 2.5 GtC due to deforestation (estimate for 1980). During the last decade (1980 - 1989) about 48% of the anthropogenic emissions have stayed in the atmosphere, the remainder has been taken up by the oceans and possibly by land ecosystems. Our qualitative knowledge of the global carbon cycle is, in view of the complexity of this cycle, relatively good. However, the current quantitative estimates of sources and of sinks of CO_2 do not balance; the atmospheric increase is less rapid than expected from carbon cycle models (in which CO_2 fertilization or environmental responses of the biosphere are not included). This, and model analyses of the interhemispheric CO_2 gradient, indicate that the northern hemisphere terrestrial ecosystems may act as a significant sink of carbon. Such a sink has, however, not been directly identified. To summarize: the total annual input of anthropogenic CO_2 is currently (1980-1989) about 7.0±1.1 GtC, assuming a central value for the input of CO_2 from tropical deforestation; the annual uptake by the oceans is estimated (based on the box models, GCMs and Tans et al, 1990) to be about 2.0±1.0 GtC; and the annual atmospheric accumulation is about 3.4±0.2 GtC. Thus, the annual sequestering by the terrestrial biosphere should be about 1.6±1.5 GtC. While several mechanisms have been suggested that could sequester carbon in terrestrial ecosystems, it is difficult to account for the total required sink. Therefore, it appears likely that, (i) the uptake of CO_2 by the oceans is underestimated, (ii) there are important unidentified processes in terrestrial ecosystems that can sequester CO_2, and/or (iii) the amount of CO_2 released from tropical deforestation is at the low end of current estimates.

If the land biota presently act as a sink of carbon due to a fertilization effect, then they might get saturated with respect to this fertilization some time in the future. This means that we cannot assume, that the terrestrial sink, which may be active currently, will continue to exist unchanged through the next century.

In order to avoid a continued rapid growth of CO_2 in the atmosphere, severe reductions on emissions will be necessary. The time taken for atmospheric CO_2 to adjust to changes in sources or sinks is of the order of 50-200 years, determined mainly by the slow exchange of carbon between surface waters and deeper layers of the ocean. Even if all anthropogenic emissions of CO_2 were halted, the atmospheric concentration would decline only slowly, and it would not approach its pre-industrial level for many hundreds of years. Thus, any reductions in emissions will only become fully effective after a time of the order of a century or more. Based on some model estimates, which neglect the feedbacks discussed earlier, the atmospheric concentration in the year 2050 would be between 530 - 600 ppmv for a constant relative growth of the annual anthropogenic emissions by 2% per year, and between 415 - 480 ppmv (increasing to 460 - 560 ppmv by the year 2100) for a constant anthropogenic emission rate at the 1990 level. In order not to exceed 420 ppmv (50% above pre-industrial), annual anthropogenic emissions would have to be reduced continuously to about 50% of their present value by the year 2050. In order to stabilize concentrations at present day concentrations (353 ppmv), an immediate reduction in global anthropogenic emissions by 60-80 percent would be necessary. The size of the estimated reduction depends on the carbon cycle model used.

During the millennium preceding the anthropogenic CO_2 growth, the concentration was relatively constant near 280 ppmv, with a variability of less than ± 10 ppmv. This indicates that the sensitivity of atmospheric CO_2 levels to minor climatic changes such as the Little Ice Age, where global mean temperatures probably decreased by about 1°C, is within this range.

However, the anticipated climatic and environmental changes may soon become large enough to act back on the oceanic and terrestrial carbon cycle in a more substantial way. A close interaction between climate variations and the carbon cycle is evidenced by the glacial-interglacial CO_2 variations. The ice-core record shows that CO_2 concentrations during the coldest part of the last glaciation were about 30% lower than during the past 10,000 years. The glacial-interglacial CO_2 variations were probably due to changes in ocean circulation and marine biological activity, and were correlated to variations in global climate. There is some (not fully clear) evidence from ice cores that rapid changes of CO_2, ca. 50 ppmv within about a century, occurred during and at the end of the ice age.

If global temperatures increase, this could change the natural fluxes of carbon, thus having feedback effects on atmospheric CO_2. Some of the identified feedbacks are potentially large and could significantly influence future CO_2 levels. They are difficult to quantify, but it seems likely that there would be a net positive feedback, i.e., they will enhance the man-made increase. On the longer term, the possibility of unexpected large changes in the mechanisms of the carbon cycle due to a human-induced change in climate cannot be excluded.

1.3 METHANE

Methane is a chemically and radiatively active trace gas that is produced from a wide variety of anaerobic (i.e., oxygen deficient) processes and is primarily removed by reaction with hydroxyl radicals (OH) in the troposphere. Oxidation of CH_4 by OH in the stratosphere is a significant source of stratospheric water (H_2O) where it is an important greenhouse gas.

1.3.1 Atmospheric Distribution of Methane

1.3.1.1 Paleo atmospheric record of methane

There are good data on the atmospheric concentration of CH_4 (Figure 9) from Antarctic and Greenland ice cores for the period between 10,000 and 160,000 years ago (Raynaud et al. 1988; Stauffer et al. 1988; Craig and Chou, 1982; Chappellaz et al. 1989). The minimum concentration during the last glacial periods (about 20,000 and 150,000 years ago) was around 0.35 ppmv, and rose rapidly, in phase with the observed temperature increases, to about 0.65 ppmv during the glacial-interglacial transitions (about 15,000 and 130,000 years ago). The atmospheric concentrations of CH_4 decreased rapidly, prior to, and during the last deglaciation period about 10,000 - 11,000 years ago (the Younger Dryas period when there were abrupt temperature decreases in Greenland and northern Europe), and increased rapidly thereafter.

Because of the brittle nature of the ice cores, data on the atmospheric concentrations of CH_4 are reliable only during the last 2,000years of the Holocene period (last 10,000 years)

1.3.1.2 Contemporary record of methane

Ice core data (Figure 1.10) indicate that the atmospheric concentrations of CH_4 averaged around 0.8 ppmv between two hundred and two thousand years ago, increasing to 0.9 ppmv one hundred years ago (Craig and Chou, 1982; Rasmussen and Khalil, 1984; Stauffer et al. 1985; Pearman and Fraser, 1988; Pearman et al., 1986; Etheridge et al., 1988). Since then, the atmospheric concentration of CH_4 has increased smoothly to present levels, highly correlated with global human population. Analysis of infrared solar spectra has shown that the atmospheric concentration of CH_4 has increased by about 30% over the last 40 years (Rinsland et al. 1985; Zander et al. 1990).

Atmospheric concentrations of CH_4 have been measured directly since 1978 when the globally averaged value was 1.51 ppmv (e.g., Rasmussen and Khalil, 1981; Blake and Rowland, 1988). Currently the value is 1.72 ppmv, corresponding to an atmospheric reservoir of about 4900 Tg (1 Tg = 10^{12} g) and it is increasing at a rate of 14 to 17 ppbv per year (40 to 48 Tg per year), i.e., 0.8 to 1.0% per year (Blake and Rowland, 1988; Steele et al. 1987). The atmospheric concentration of CH_4 in the Northern Hemisphere is 1.76 ppmv, compared to 1.68 ppmv in the Southern Hemisphere (Figure 1.11). The magnitude of the seasonal

variability varies with latitude (Steele et al. 1987; Fraser et al. 1984), being controlled by the temporal variability in source strengths and atmospheric concentration of OH radicals,

1.3.1.3 Isotopic composition of methane

Methane is produced from different sources with distinctive proportions of carbon ^{12}C, ^{13}C, and ^{14}C, and hydrogen isotopes H, D (^{2}H), and T (^{3}H). Similarly, the rates of processes that destroy CH_4 depend upon its isotopic composition. Consequently, the CH_4 budget can be constrained by knowledge of the isotopic composition of atmospheric CH_4, the extent of isotopic fractionation during removal, and the isotopic signatures of CH_4 from different sources. Recent work to elucidate the sources of CH_4 has proceeded through an analysis of carbon isotopic signatures (Cicerone and Oremland, 1988; Wahlen et al., 1989; Lowe et al., 1988; and references therein). One example of this is an analysis of ^{14}C data which suggests that about 100 Tg CH_4 per year may arise from fossil sources (Cicerone and Oremland, 1988; Wahlen et al., 1989). Such a distinction is possible because CH_4 from fossil sources is ^{14}C-free, while that from other sources has essentially the ^{14}C concentration of modern carbon.

1.3.2 Sinks of Methane

The major sink for atmospheric CH_4 is reaction with OH in the troposphere, the OH concentration being controlled by a complex set of reactions involving CH_4, CO, NMHC, NO_x, and tropospheric O_3 (discussed in Section 1.7; Sze, 1977; Crutzen, 1987). Based on the reaction rate coefficient between CH_4 and OH, and the estimated tropospheric distribution of OH, an atmospheric life-time for CH_4 of between 8 and 11.8 years has been estimated (Prinn et al. 1987). This estimate is supported by the fact that models of global OH are tested by analyses of the budgets for CH_3CCl_3 (Logan et al., 1981; Fraser et al., 1986a; Prinn et al., 1987) and ^{14}CO (Appendix to WMO, 1989b). The reaction between CH_4 and OH currently represents a sink of 400 to 600 Tg of CH_4 per year. The efficiency of this sink may, however, have decreased during the last century because the atmospheric concentration of OH in the troposphere may have decreased, hence the lifetime of CH_4 would have increased, in response to increasing concentrations of CO, NMHC, and CH_4 (Sze, 1977).

Soils may represent a removal mechanism for CH_4. The magnitude of this sink has been estimated (this assessment) to be 30±15 Tg CH_4 per year from the work of Harris et al., 1982 and Seiler and Conrad, 1987.

1.3.3 Sources of Methane

Methane is produced from a wide variety of anaerobic sources (Cicerone and Oremland, 1988). Two main pathways for CH_4 production have been identified: (i) reduction of CO_2 with hydrogen, fatty acids or alcohols as hydrogen donors, or (ii) transmethylation of acetic acid or methyl alcohol by CH_4-producing bacteria. Table 2 summarizes identified sources of CH_4 with ranges of likely annual emissions. The total annual CH_4 source must equal the atmospheric sink of about 500 (400 to 600) Tg CH_4 per year, the possible soil sink of about 30 (15 to 45) Tg CH_4 per year, and the annual growth of 40 to 48 Tg CH_4 in the atmosphere. The sum of the present best estimates of the sizes of the individual sources identified in Table 2 equal 525 Tg CH_4 per year. It should be noted that the newest data for rice paddies, biomass burning, and coal mining sources suggest that the values may be even less than those of Table 2, possibly indicating a missing source of CH_4, or an overestimate of the sink for CH_4.

Table 2

ESTIMATED SOURCES AND SINKS OF METHANE

	Annual Release (Tg CH_4)	Range (Tg CH_4)
Source		
Natural Wetlands (bogs, swamps, tundra, etc)	115	100 - 200
Rice Paddies	110	25 - 170
Enteric Fermentation (animals)	80	65 - 100
Gas Drilling, venting, transmission	45	25 - 50
Biomass Burning	40	20 - 80
Termites	40	10 - 100
Landfills	40	20 - 70
Coal Mining	35	17 - 50
Oceans	10	5 - 20
Freshwaters	5	1 - 25
CH_4 Hydrate Destabilization	5	0 - 100
Sink		
Removal by soils	30	15-45
Reaction with OH in the atmosphere	500	400 - 600
Atmospheric Increase	44	40 - 48

1.3.3.1 Natural wetlands

Significant progress has been made in quantifying the magnitude of the source of CH_4 from natural wetlands (Svensson and Rosswall, 1984; Sebacher et al. 1986; Whalen and Reeburgh, 1988; Moore and Knowles, 1987; Mathews and Fung, 1987; Harris et al. 1985; Crill et al. 1988; Andronova, 1989; Harris and Sebacher, 1981; Burke et al, 1988; Harris et al, 1988; Aselmann and Crutzen, 1989). Recent data support earlier estimates of a global flux of 110 - 115 Tg CH_4 per year, but reverses the relative importance of tropical and high latitude systems. The data base, which is still quite limited (no data from Asia), suggests 55 Tg CH_4 per year (previously 32 Tg CH_4 per year) from tropical wetlands, and 39 Tg CH_4 per year (previously 63 Tg CH_4 per year) from high latitude wetlands. Since CH_4 is produced through biological processes under anaerobic conditions, any factors affecting the physical, chemical or biological characteristics of soils could affect CH_4 emission rates.

1.3.3.2 Rice paddies

Rice paddies are an important source of CH_4 with estimates of the globally averaged flux ranging from 25 - 170 Tg CH_4 per year (Neue and Scharpenseel, 1988; Yagi and Minami, 1989; Holzapfel-Pschorn and Seiler, 1986; Cicerone and Shetter, 1981; Cicerone et al. 1983). The flux of CH_4 from rice paddies is critically dependent upon several factors including: (i) agricultural practices (e.g., fertilization, water management, density of rice plants, double cropping systems, application of manure or rice straw), (ii) soil / paddy characteristics (soil type, acidity, redox potential, temperature, nutrient availability, substrate, profile of anaerobic environment), and (iii) time of season. One difficulty in obtaining accurate estimates is that almost 90% of the world's harvested area of rice paddies is in Asia, and of this about 60% are in China and India from which no detailed data is available. The annual production of rice since 1940 has approximately doubled as a result of double cropping practices and an increased area of cultivation. It is likely that CH_4 emissions have increased proportionally as well.

1.3.3.3 Biomass burning

Biomass burning in tropical and sub-tropical regions is thought to be a significant source of atmospheric CH_4, with estimates of global emission rates ranging from 20 to 80 Tg CH_4 per year (Andreae et al. 1988; Bingemer and Crutzen, 1987; Crutzen et al. 1979; Crutzen et al. 1985; Crutzen, 1989; Greenberg et al. 1984; Stevens et al. 1990; Quay et al. 1990). Improved estimates require an enhanced understanding of: (i) CH_4 emission factors, (ii) the amount, by type, of vegetation burnt each year on an area basis, and (iii) type of burning (smouldering vs flaming). Current estimates indicate that over the last century the rate of forest clearing by burning has increased (cf. Section 1.2.2.2).

1.3.3.4 Enteric fermentation (animals)

Methane emissions from enteric fermentation in ruminant animals, including all cattle, sheep and wild animals, is estimated to provide an atmospheric source of 65 - 100 Tg CH_4 per year (Crutzen et al. 1986; Lerner et al., 1988). Methane emissions depend upon animal populations, as well as the amount and type of food. It is difficult to accurately estimate the change in this source over the last century because the significant increase in the number of cattle and sheep has been partially offset by decreases in the populations of elephants and North American bison. One estimate suggests that the magnitude of this source has increased from 21 Tg CH_4 per year in 1890 to 78 Tg CH_4 per year in 1983 (Crutzen et al. 1986).

1.3.3.5 Termites

There is a large range in the magnitude of the estimated fluxes of CH_4 from termites; 10 - 100 Tg CH_4 per year (Cicerone and Oremland, 1988; Zimmerman et al. 1982; Rasmussen and Khalil, 1983; Seiler et al. 1984; Fraser et al. 1986b). The values are based on the results of laboratory experiments, applied to estimates of global termite populations and the amount of biomass consumed by termites, both of which are uncertain, and field experiments. It is important to determine whether the global termite population is currently increasing, and whether it is likely to respond to changes in climate.

1.3.3.6 Landfills

The anaerobic decay of organic wastes in landfills may be a significant anthropogenic source of atmospheric CH_4, 20 - 70 Tg CH_4 per year. However, several factors need to be studied in order to quantify the magnitude of this source more precisely, including amounts, trends, and types of waste materials, and landfill practices (Bingemer and Crutzen, 1987).

1.3.3.7 Oceans and freshwaters

Oceans and freshwaters are thought to be a minor source of atmospheric CH_4. The estimated flux of CH_4 from the oceans is based on a limited data set, taken in the late 1960's / early 1970's when the atmospheric concentration of CH_4 was about 20% lower. They showed that the open oceans were only slightly supersaturated in CH_4 with respect to its partial pressure in the atmosphere. There are inadequate recent data from either the open oceans or coastal waters to reduce the uncertainty in these estimates (Cicerone and Oremland, 1988).

1.3.3.8 Coal mining

Methane is released to the atmosphere from coal mine ventilation, and degassing from coal during transport to an end-use site. A recent unpublished study estimated the flux of CH_4 from coal mining, on a country basis, for the ten major coal producing countries, and deduced a global minimum emission of 17 Tg CH_4 per year. Global CH_4 fluxes from coal mining have been estimated to range from 10 - 50 Tg CH_4 per year (Cicerone and Oremland, 1988, and recent unpublished studies by others).

1.3.3.9 Gas drilling, venting and transmission

CH_4 is the major component of natural gas, hence leakage from pipelines and venting from oil and gas wells could represent a significant source of atmospheric CH_4 (Cicerone and Oremland, 1988). The global flux from these sources is estimated, based on limited data of questionable reliability, to range from 25 - 50 Tg CH_4 per year.

1.3.4 Feedbacks from Climate Change into the Methane Cycle

Future atmospheric concentrations of CH_4 will depend on changes in the strengths of either the sources or sinks, which are dependent upon social, economic, and political, and also environmental factors and in particular changes in climate. Methane emissions from wetlands are particularly sensitive to temperature and soil moisture, and hence future climatic changes could significantly change the fluxes of CH_4 from both natural wetlands and rice paddies. Tropospheric OH, which provides the atmospheric sink for CH_4, is dependent upon a number of factors, including the intensity of UV-B radiation, and the ambient concentrations of H_2O, CO, CH_4, reactive nitrogen oxides, and tropospheric O_3 (See Section 1.7) (Crutzen, 1987; Isaksen and Hov, 1987; Thompson and Cicerone, 1986).

1.3.4.1 Tropical methane sources

The major sources of CH_4 in tropical regions (natural wetlands and rice paddies) are quite sensitive to variations in soil moisture. Consequently, changes in soil moisture, which would result from changes in temperature and precipitation, could significantly alter the magnitude of these large sources of atmospheric CH_4. Increased soil moisture would result in larger fluxes, whereas a decrease in soil moisture would result in smaller fluxes.

1.3.4.2 High latitude methane sources

Methane fluxes from the relatively flat tundra regions would be sensitive to changes of only a few centimetres in the level of the water table, with flooded soils producing a factor of 100 more CH_4 than dry soils (Whalen and Reeburgh, 1988; Crill et al. 1988). Similarly, emissions of CH_4 are significantly larger at warmer temperatures, due to accelerated microbiological decomposition of organic material in the near-surface soils. Consequently, an increase in soil moisture and temperatures in high latitude wetlands would result in enhanced CH_4 emissions, whereas warmer dryer soils might have decreased CH_4 emissions.

Higher temperatures could also increase the fluxes of CH_4 at high northern latitudes from; (i) CH_4 trapped in permafrost, (ii) decomposable organic matter frozen in the permafrost, and (iii) decomposition of CH_4 hydrates (Cicerone and Oremland, 1988; Kvenvolden, 1988). Quantifying the magnitudes of these positive feedbacks is difficult. Timescales for thawing the permafrost, located between a few centimetres to metres below the surface, could be decades to centuries, while the time for warming the CH_4 hydrates could be even longer, although one study (Kvenvolden, 1988) estimated that the flux of CH_4 from hydrate decomposition could reach 100 Tg CH_4 per year within a century.

1.3.5 Conclusions

Current atmospheric CH_4 concentrations, at 1.72 ppmv, are now more than double the pre-industrial value (1750-1800) of about 0.8 ppmv, and are increasing at a rate of 0.9% per year. The ice core record shows that CH_4 concentrations were about 0.35 ppmv during glacial periods, and increased in phase with temperature during glacial-interglacial transitions. The current atmospheric concentration of CH_4 is greater than at any time during the last 160,000 years.

Reaction with OH in the troposphere, the major sink for CH_4, results in a relatively short atmospheric lifetime of 10 ± 2 years. The short lifetime of CH_4 implies that atmospheric concentrations will respond quite rapidly, in comparison to the longer lived gases such as CO_2, N_2O, and CFCs, to changes in emissions. In order to stabilize concentrations at present day levels, an immediate reduction in global man-made emissions by 15-20 percent would be necessary (this and other scientific sensitivity analyses are discussed in the Annex). Global concentrations of OH are dependent upon the intensity of UV-B radiation, and the concentrations of gases such as H_2O, CO, CH_4, NO_x, NMHC, and O_3, and may have declined during the 20th century due to changes in the atmospheric concentrations of these gases.

The individual sources of atmospheric CH_4 have been qualitatively identified, but there are significant uncertainties in the magnitude of their strengths. Human activities such as rice cultivation, rearing of domestic ruminants, biomass burning, coal mining, and natural gas venting have increased the input of CH_4 into the atmosphere, and these combined with an apparent decrease in the concentration of tropospheric OH, yields the observed rise in global CH_4. However, the quantitative importance of each of the factors contributing to the observed increase is not well known at present.

Several potential feedbacks exist between climate change and CH_4 emissions, in both tropical and high latitude wetland sources. In particular, an increase in high latitude temperatures could result in a significant release of CH_4 from the melting of permafrost and decomposition of CH_4 hydrates.

1.4 HALOCARBONS

Chlorine and bromine containing halocarbons have been shown to deplete O_3 in the stratosphere. In addition, it has been recognized that they are important greenhouse gases. Their sources, sinks, atmospheric distributions, and role in perturbing stratospheric O_3 and the Earth's radiative balance have been reviewed in detail (WMO 1985, 1989a, 1989b). Many governments, recognizing the harmful effects of halocarbons on the environment, signed the "Montreal Protocol on Substances that Deplete the Ozone Layer" (UNEP, 1987) in 1987 to limit the production and consumption of a number of fully halogenated CFCs and halons. The control measures of the Montreal Protocol freeze the production and consumption of CFCs 11, 12, 113, 114, and 115 in developed countries at their 1986 levels from the year 1990, a reduction to 80% of their 1986 levels from the year 1993, with a further reduction to 50% of their 1986 levels from the year 1998. Developing countries, with a per capita use of CFCs of less than 0.3 kg per capita, are allowed to increase their per capita use up to this limit and can delay compliance with the control measures by 10 years. All major producing and consuming developed countries, and many developing countries, have signed and ratified the Montreal Protocol.

1.4.1 Atmospheric Distribution of Halocarbons

The mean atmospheric concentrations of the most abundant radiatively active halocarbons are shown in Table 3. The atmospheric concentrations of the halocarbons are currently increasing more rapidly on a global scale (on a percentage basis) than the other greenhouse gases (Figure 1.12). The concentrations of the fully halogenated chlorofluorocarbons (CFCs), slightly greater in the northern hemisphere than in the southern hemisphere, are consistent with the geographical distribution of releases (>90% from the industrialized nations), a 45 ^oN - 45 ^oS mixing time of about 1 year, and their very long atmospheric lifetimes.

1.4.2 Sinks for Halocarbons

There is no significant tropospheric removal mechanism for the fully halogenated halocarbons such as CCl_3F (CFC-11), CCl_2F_2 (CFC-12), $C_2Cl_3F_3$ (CFC-113), $C_2Cl_2F_4$ (CFC-114), C_2ClF_5 (CFC-115), carbon tetrachloride (CCl_4), and halon 1301 ($CBrF_3$). They have long atmospheric lifetimes, decades to centuries, and are primarily removed by photodissociation in the mid - upper stratosphere. There is currently a significant imbalance between the sources and sinks giving rise to a rapid growth in atmospheric concentrations. To stabilize the atmospheric concentrations of CFCs 11, 12 and 113 at current levels would require reductions in emissions of approximately 70-75%, 75-85%, and 85-95%, respectively (see Annex).

Non-fully halogenated halocarbons containing a hydrogen atom such as methyl chloride (CH_3Cl), methylchloroform (CH_3CCl_3), $CHClF_2$ (HCFC-22), and a number of other HCFCs and HFCs being considered as substitutes for the current CFCs (c.f. Section 1.4.4) are primarily removed in the troposphere by reaction with OH. These hydrogen containing species

have atmospheric lifetimes ranging from about one to forty years, much shorter on average than the fully halogenated CFCs. To stabilize the atmospheric concentrations of HCFC-22 at current levels would require reductions in emissions of approximately 40-50%.

TABLE 3

Halocarbon Concentrations and Trends (1990) †

Halocarbon		Mixing Ratio pptv	Annual Rate of Increase pptv	Annual Rate of Increase %	Lifetime Years
CCl_3F	(CFC-11)	280	9.5	4	65
CCl_2F_2	(CFC-12)	484	16.5	4	130
$CClF_3$	(CFC-13)	5			400
$C_2Cl_3F_3$	(CFC-113)	60	4-5	10	90
$C_2Cl_2F_4$	(CFC-114)	15			200
C_2ClF_5	(CFC-115)	5			400
CCl_4		146	2.0	1.5	50
$CHClF_2$	(HCFC-22)	122	7	7	15
CH_3Cl		600			1.5
CH_3CCl_3		158	6.0	4	7
$CBrClF_2$	(halon 1211)	1.7	0.2	12	25
$CBrF_3$	(halon 1301)	2.0	0.3	15	110
CH_3Br		10-15			1.5

† There are a few minor differences between the lifetimes reported in this table and the equivalent table in WMO 1989b. These differences are well within the uncertainty limits. The 1990 mixing ratios have been estimated based upon an extrapolation of measurements reported in 1987 or 1988, assuming that the recent trends remained approximately constant.

1.4.3 Sources of Halocarbons

Most halocarbons, with the notable exception of CH_3Cl, are exclusively of industrial origin. Halocarbons are used as aerosol propellants (CFCs 11, 12, and 114), refrigerants (CFCs 12 and 114, and HCFC-22), foam blowing agents (CFCs 11 and 12), solvents (CFC-113, CH_3CCl_3, and CCl_4), and fire retardants (halons 1211 and 1301). The atmospheric concentration of methyl chloride is about 0.6 ppbv, and is primarily released from the oceans and during biomass burning. There is no evidence that the atmospheric concentration of CH_3Cl is increasing. Methyl bromide (CH_3Br) is produced by oceanic algae, and there is evidence that its atmospheric concentration has been increasing in recent times due to a significant anthropogenic source (Penkett et al., 1985; Wofsy et al., 1975).

1.4.4 Future Atmospheric Concentration of Halocarbons

Future emissions of CFCs 11, 12, 113, 114, and 115 will be governed by the Montreal Protocol on "Substances that Deplete the Ozone Layer " as discussed in Section 1.4. In addition, international negotiations are currently in progress that will likely (i) result in a complete global phase-out of production of these chemicals by the year 2000, and (ii) enact limitations on the emissions (via production and consumption controls) of CCl_4, and CH_3CCl_3. However, even with a complete cessation of production of CFCs 11, 12 and 113 in the year 2000 their atmospheric concentrations will still be significant for at least the next

century because of their long atmospheric lifetimes. It should be noted that emissions of these gases into the atmosphere will continue for a period of time after production has ceased because of their uses as refrigerants, foam blowing agents, fire retardants, etc.

A number of hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) are being considered as potential replacements for the long-lived CFCs (11, 12, 113, 114, and 115) that are regulated under the terms of the Montreal Protocol. The HFCs and HCFCs primarily being considered include: HCFC-22, HCFC-123 ($CHCl_2CF_3$), HCFC-124 ($CHClFCF_3$), HFC-125 (CHF_2CF_3), HFC-134a (CH_2FCF_3), HCFC-141b (CH_3CCl_2F), HCFC-142b (CH_3CClF_2), HFC-143a (CH_3CF_3), and HFC-152a (CH_3CHF_2). The calculated atmospheric lifetimes of these chemicals are controlled primarily by reaction with tropospheric OH and range between about 1 and 40 years. It has been estimated (UNEP, 1989) that a mix of HFCs and HCFCs will replace the CFCs currently in use at a rate of about 0.4 kg of substitute for every kg of CFCs currently produced, with an annual growth rate of about 3%. Because of their shorter lifetimes, and expected rates of substitution and emissions growth rates, the atmospheric concentrations of HFCs and HCFCs will be much lower for the next several decades than if CFCs had continued to be used, even at current rates. However, continued use, accompanied by growth in the emission rates, of HFCs and HCFCs for more than several decades would result in atmospheric concentrations that would be radiatively important.

1.4.5 Conclusions

The atmospheric concentrations of the industrially produced halocarbons, primarily CCl_3F, CCl_2F_2, $C_2Cl_3F_3$, and CCl_4 are about 280 pptv, 484 pptv, 60 pptv, and 146 pptv, respectively. Over the past few decades their concentrations (except CCl_4) have increased more rapidly (on a percentage basis) than the other greenhouse gases, currently at rates of at least 4% per year. The fully halogenated CFCs and CCl_4 are primarily removed by photolysis in the stratosphere, and have atmospheric lifetimes in excess of 50 years.

Most halocarbons, with the notable exception of methyl chloride, are exclusively anthropogenic and their sources (solvents, refrigerants, foam blowing agents, and aerosol propellants) are well understood.

To stabilize, and then reduce, the current atmospheric concentrations of the fully halogenated CFCs (e.g., 11, 12 and 113) would require approximate reductions in emissions of 70-75%, 75-85%, and 85-95%, respectively. Future emissions of CFCs and CCl_4 will, most likely, be eliminated or be significantly lower than today's because the stringency, scope, and timing of international regulations on chlorine and bromine containing chemicals, i.e., the Montreal Protocol on Substances that Deplete the Ozone Layer, are currently being renegotiated. However, the atmospheric concentrations of CFCs 11, 12 and 113 will still be significant (30 - 40% of current) for at least the next century because of their long atmospheric lifetimes.

1.5 NITROUS OXIDE

Nitrous oxide is a chemically and radiatively active trace gas that is produced from a wide variety of biological sources in soils and water and is primarily removed in the stratosphere by photolysis and reaction with electronically excited oxygen atoms.

1.5.1 Atmospheric Distribution of Nitrous Oxide

The mean atmospheric concentration of N_2O in 1990 is about 310 ppbv, corresponding to a reservoir of about 1500 Tg N, and increasing at a rate of 0.2 - 0.3% per year (Figure 1.13; Weiss, 1981; Prinn et al. 1990; Robinson et al. 1988; Elkins and Rossen, 1989; Rasmussen and Khalil, 1986). This observed rate of increase represents an atmospheric growth rate of about 3 to 4.5 Tg N per year. The atmospheric concentration of N_2O is higher in the northern

hemisphere than in the southern hemisphere by about 1 ppbv. Ice core measurements show that the pre-industrial value of N_2O was relatively stable at about 285 ppbv for most of the past 2000 years, and started to increase around the year 1700 (Figure 1.14; Pearman et al., 1986; Khalil and Rasmussen, 1988a; Etheridge et al. 1988; Zardini et al. 1989). Figure 1.14 shows that the atmospheric concentrations of N_2O may have decreased by a few ppbv during the period of the mini ice-age.

1.5.2 Sinks for Nitrous Oxide

The major atmospheric loss process for N_2O is photochemical decomposition in the stratosphere, and is calculated to be 10± 3 Tg N per year (Table 4). Nitrous oxide has an atmospheric lifetime of about 150 years. The observed rate of growth represents a 30% imbalance between the sources and sinks (Hao et al. 1987). Tropospheric sinks such as surface loss in aquatic and soil systems are considered to be small (Elkins et al. 1978, Blackmer and Bremner, 1976).

1.5.3 Sources of Nitrous Oxide

1.5.3.1 Oceans

The oceans are a significant, but not dominant source of N_2O (McElroy and Wofsy, 1986). Based on measurements of the concentration gradients between the atmosphere and surface waters (Butler et al. 1989, and NOAA GMCC unpublished data), and on estimates of the gas exchange coefficient, the current estimate of the magnitude of the ocean source ranges from 1.4 - 2.6 Tg N per year, significantly lower than earlier estimates (Elkins et al. 1978; Cohen and Gordon, 1979; Cline et al. 1987). An accurate determination of the global annual ocean flux is difficult because of uncertainties associated with quantifying the gas exchange coefficient and because the partial pressure of N_2O in the surface waters is highly variable, both spatially and temporally. The partial pressure of N_2O in surface waters varies considerably, ranging from being supersaturated by up to 40% in upwelling regions to being undersaturated by a few percent in areas around Antarctica and within gyres. Data suggest that during El Niño events, where upwelling in the Pacific ocean is suppressed, the ocean fluxes of N_2O are significantly lower (Cline et al. 1987; Butler et al. 1989). It is still unclear whether N_2O is primarily produced from nitrification in near surface waters, or denitrification in oxygen deficient deep waters. Based on vertical profile measurements of oceanic N_2O (NOAA GMCC, unpublished) the oceanic reservoir has been estimated to be between 900 and 1100 Tg N, comparable to the atmosphere. Consequently, changes in the exchange fluxes of N_2O between the ocean and the atmosphere could significantly impact its atmospheric concentration.

1.5.3.2 Soils

Denitrification in aerobic soils is thought to be a dominant source of atmospheric N_2O (Keller et al. 1986; Matson and Vitousek, 1987; Matson and Vitousek, 1989; Slemr et al. 1984). Nitrification under anaerobic conditions could, however, produce higher yields of N_2O per unit of transformed nitrogen. Quantification of global N_2O emissions from soils is difficult because of the heterogeneity of terrestrial ecosystems and the variability in environmental conditions that control the fluxes of N_2O.

Estimates of global fluxes of N_2O from tropical forests range from 2.2 - 3.7 Tg N per year. The impact of deforestation on the emissions of N_2O from tropical soils is unclear, with some studies suggesting that the emissions of N_2O from deforested land are enhanced by as much as a factor of three (Luizao et al. 1989), whereas other studies concluded that N_2O fluxes decreased if vegetation did not return (Robertson and Tiedje, 1988).

Quantifying the roles of temperate forest soils and grasslands in the N_2O budget is difficult because of the paucity of data, and conflicting results. Estimates of N_2O fluxes from temperate forest soils range from 0.7 - 1.5 Tg N per year in one study (Schmidt et al. 1988), to almost none in another study (Bowden et al. 1989). One study also reported that deforestation in temperate forests would lead to enhanced emissions of N_2O (Bowden and Bormann, 1986).

Reliable global N_2O fluxes from grasslands are impossible to derive from the fragmented data available. One study (Ryden, 1981) concluded that English grassland soils, with no fertilization, are a sink for N_2O, whereas limited studies of tropical grasslands and pastures suggest that they may be a moderate to significant source of N_2O (Luizao et al. 1989; Robertson and Tiedje, 1988).

1.5.3.3 Combustion

Until recently, the combustion of fossil fuels was thought to be an important source of atmospheric N_2O (Pierotti and Rasmussen, 1976; Weiss and Craig, 1976; Hao et al. 1987). However, a recent study has shown that the earlier results are incorrect because N_2O was being artificially produced in the flasks being used to collect N_2O from combustion sources (Muzio and Kramlich, 1988). The latest estimate of the global flux of N_2O from combustion sources is between 0.1 and 0.3 Tg N per year, compared to earlier values which were as high as 3.2 Tg N per year.

1.5.3.4 Biomass Burning

Biomass burning is now thought to be a minor source of atmospheric N_2O with a global flux of less than 0.2 Tg N per year (Muzio and Kramlich, 1988; Crutzen 1989; Elkins et al. 1990; Winstead et al. 1990; Griffith et al. 1990). This value is 1-2 orders of magnitude less than previous estimates (Crutzen et al. 1979, 1985) which were influenced by artifacts involving N_2O analysis (Crutzen et al., 1985) and N_2O production in sampling flasks (Muzio and Kramlich, 1988).

1.5.3.5 Fertilizer / Ground-Water

Nitrous oxide production from the use of nitrate and ammonium fertilizers is difficult to quantify because the N_2O fluxes are dependent upon numerous factors including type of fertilizer, soil type, soil temperature, weather, and farming practices (e.g., ploughing, sowing, irrigating). Conversion of fertilizer N to N_2O ranges from 0.01 - 2.0% (Conrad et al. 1983; Bremner et al. 1981). This range, coupled with a global fertilizer production of 55 Tg N per year in 1980, results in a total N_2O emission of between 0.01 - 1.1 Tg N per year (Conrad et al. 1983). Leaching of nitrogen fertilizers from soils into groundwater may result in additional fluxes of N_2O up to 1.1 Tg N per year (Conrad et al. 1983; Ronen et al. 1988). Consequently, a range of 0.01 - 2.2 Tg N per year can be derived for the flux of N_2O from fertilizer use.

1.5.4 Conclusions

Nitrous oxide is a greenhouse gas whose atmospheric concentration, at 310 ppbv, is now about 8% greater than in the pre-industrial era, and is increasing at a rate of about 0.2 - 0.3% per year, corresponding to about 3 - 4.5 Tg N per year. This represents an excess of 30% of current global emissions over current sinks. The major sink for N_2O is photolysis in the stratosphere, resulting in a relatively long atmospheric lifetime of about 150 years. The magnitude of the sink for N_2O is relatively well known ($\pm$ 30%). In order to stabilize concentrations at present day levels, an immediate reduction of 70 - 80% of the additional flux of N_2O that has occurred since the pre-industrial era would be necessary. .

Quantification of the various natural and anthropogenic sources is uncertain. Since the latest studies indicate that the total combined flux of N_2O from combustion and biomass burning is between 0.1 to 0.5 Tg N per year, in contrast to earlier estimates of about 5 Tg N per year, and production of N_2O from fertilizer (including groundwater) is believed to be less than or equal to 2.2 Tg N per year, it is difficult to account for the annual increase based on known sources. Stimulation of biological production due to agricultural development may account for the missing anthropogenic emissions. Estimates of the removal rate of N_2O by photodissociation in the stratosphere range from 7 - 13 Tg N per year. Therefore, the total source needed to account for the observed annual atmospheric growth is 10 - 17.5 Tg N per year against a flux of N_2O from known sources of 4.4 - 10.5 Tg N per year. These data suggest that there are missing sources of N_2O, or the strengths of some of the identified sources have been underestimated. Despite these uncertainties, it is believed that the observed increase in N_2O concentrations is caused by human activities.

TABLE 4

Estimated Sources and Sinks of Nitrous Oxide

	Range (TgN per year)
Source	
Oceans	1.4 - 2.6
Soils (tropical forests)	2.2 - 3.7
(temperate forests)	0.7 - 1.5
Combustion	0.1 - 0.3
Biomass burning	0.02 - 0.2
Fertilizer (including ground-water)	0.01 - 2.2
TOTAL:	4.4 - 10.5
Sink	
Removal by soils	?
Photolysis in the stratosphere	7 - 13
Atmospheric Increase	3 - 4.5

1.6 STRATOSPHERIC OZONE

Stratospheric O_3 is an important constituent of the Earth's atmosphere. It protects the Earth's surface from harmful solar ultraviolet radiation and it plays an important role in controlling the temperature structure of the stratosphere by absorbing both incoming solar ultraviolet radiation and outgoing terrestrial (longwave) radiation. Part of the absorbed outgoing longwave radiation is then re-radiated back to the surface-troposphere system. Reductions in stratospheric O_3 can modify the surface temperature via two competing processes: more solar radiation is transmitted to the surface-troposphere system, thereby contributing to a surface warming; on the other hand, the cooler stratosphere (due to decreased solar and long-wave absorption) emits less to the troposphere which would tend to cool the surface. The solar warming (a function of total column amount of O_3) and longwave cooling (a function of the vertical distribution of O_3) are similar in magnitude. Therefore, the magnitude as well as the sign of the change in surface temperature depends critically on the magnitude of the O_3 change, which in turn is depends strongly on altitude, latitude and season.

The concentration and distribution of stratospheric O_3 is controlled by dynamical, radiative and photochemical processes. Stratospheric O_3 is photochemically controlled by chemically active species in the (i) oxygen, (ii) hydrogen, (iii) nitrogen, (iv) chlorine, and (v) bromine families. The precursors for the photochemically active species are (i) O_2, (ii) H_2O and CH_4; (iii) N_2O; (iv) CFCs, CCl_4, CH_3CCl_3, CH_3Cl, and (v) halons and CH_3Br, respectively.

1.6.1 Stratospheric Ozone Trends

1.6.1.1 Total column ozone trends

The Antarctic ozone hole, which formed during the mid to late 1970s recurs every springtime. To determine O_3 trends more widely, data from the ground-based Dobson network have been re-evaluated, station by station, and used to determine changes in total column O_3 over the past two decades. Unfortunately, the network and data are adequate for only a limited geographical

region, i.e., 30 - 64°N. They are inadequate to determine total column O_3 changes in the Arctic, tropics, subtropics, or southern hemisphere apart from Antarctica. Satellite data can provide the desired global coverage, but the current record is too short (about one solar cycle, 1978 to present), to differentiate the effects of natural and human-influenced processes on O_3. The re-evaluated data was analysed for the effects of known natural geophysical processes [seasonal variation, the approximately 26-month quasi-biennial-oscillation, and the 11-year solar cycle] and possible human perturbations. After allowing for natural variability, the analyses, using a variety of statistical models and assumptions, showed measurable zonal mean O_3 decreases in the range 3.4% to 5.1% between 30 and 64°N latitude for the winter months (December - March) between 1969 and 1988, with the larger decreases at the higher latitudes (WMO, 1989a,b). No statistically significant zonal trends were found for the summer period (May - August). Lastly, within longitudinal sectors, regional differences in the O_3 trends were indicated, with the largest values over North America and Europe and the smallest over Japan.

1.6.1.2 Changes in the vertical distribution of ozone

Substantial uncertainties remain in defining changes in the vertical distribution of O_3. Analysis of SAGE I and II satellite data, averaged over 20 to 50°N and S latitudes, indicates that near 40 km O_3 decreased by 3 ± 2 % between February 1979 - November 1981 and October 1984 - December 1988 (WMO, 1989b). Because the SAGE record is so short (i.e., less than one solar cycle), no attempt has been made to distinguish between solar-induced and human-influenced contributions to these changes. A thorough analysis of data from 10 ground-based Umkehr stations in the Northern Hemisphere for the period 1977 to 1987 indicates a statistically significant decrease in O_3 between 30 and 43 km. The decrease near 40 km of 4.8 ±3.1 %, after allowing for seasonal and solar-cycle effects and correcting the data for aerosol interferences, is broadly consistent with theoretical predictions. Based on satellite, ground-based, and ozonesonde data, there are indications of a continuing stratospheric O_3 decrease since the late 1970s of a few percent at 25 km and below. Photochemical models, which do not take into account heterogeneous processes) do not predict these changes, but the measurements are qualitatively consistent with those required for compatibility with the total column measurements.

1.6.2 Future Changes

Future changes in stratospheric O_3 are critically dependent upon future emissions of CFCs, other halocarbons, CH_4, N_2O, and CO_2. Assuming that the current regulatory measures agreed under the Montreal Protocol are not strengthened, then the chlorine loading of the atmosphere is predicted to reach about 9 ppbv by the year 2060, about three times today's level, and a bromine loading of about 30 pptv, about twice today's level . Models predict column O_3 reductions of 0 to 4% in the tropics, and from 4 to 12% at high latitudes in late winter. These predictions do not include the effects of heterogeneous processes, which play a critical role in the formation of the Antarctic ozone hole. Consequently, models that include the effects of heterogeneous processes would predict larger O_3 depletions, at least in polar regions. Ozone is predicted to decrease by 25 - 50% at 40 km and result in stratospheric temperature decreases of 10 to 20 K. If, as expected, the Montreal Protocol is modified to eliminate the emissions of CFCs 11, 12, 113, 114, 115, halons 1211 and 1301, and restrict the emissions of CCl_4 and CH_3CCl_3, by the year 2000, then the chlorine loading of the atmosphere by the year 2060 will probably lie between 2.5 and 4 ppbv (depending upon the emissions of CCl_4 and CH_3CCl_3, and HCFCs). Models that do not include heterogeneous processes predict that global O_3 levels would be similar to today. However, if the atmospheric chlorine loading approaches 4 ppbv the implications for polar O_3, and its subsequent impacts on O_3 at mid-latitudes, are unknown.

1.7 TROPOSPHERIC OZONE AND RELATED TRACE GASES (CARBON MONOXIDE, NON-METHANE HYDROCARBONS, AND REACTIVE NITROGEN OXIDES).

1.7.1 Tropospheric Ozone

Tropospheric O_3 is a greenhouse gas, of particular importance in the upper troposphere in the tropics and sub-tropics. Its distribution is controlled by a complex interplay between chemical, radiative, and dynamical processes. Ozone is: (i) transported down into the troposphere from the stratosphere; (ii) destroyed by vegetative surfaces; (iii) produced by the photo-oxidation of CO, CH_4, and NMHC in the presence of reactive nitrogen oxides (NO_x), and (iv) destroyed by uv-photolysis and by reaction with hydrogen oxide radicals (HO_2) (Danielsen, 1968; Mahlman and Moxim, 1978; Galbally and Roy, 1980; Crutzen, 1974; Isaksen et al., 1978). Chemical processes in clouds could have a strong influence on O_3 production and destruction rates (Lelieveld and Crutzen, 1990).

Consequently, while CO, NMHC, and NO_x are not important greenhouse gases in themselves, they are important precursors of tropospheric O_3 and they are therefore treated in some detail in this subsection.

1.7.1.1 Atmospheric distribution

Ozone in the troposphere has a lifetime of at most several weeks, hence its concentration varies with latitude, longitude, altitude and season (Chatfield and Harrison, 1977; Logan, 1985). Near the surface monthly mean concentrations (30 - 50 ppbv) are highest in spring and summer at northern mid-latitudes (Figure 1.15). In the middle troposphere at northern mid-latitudes values are highest also in spring and summer, 60 - 65 ppbv. The summer maximum results from photo-oxidation of O_3 precursors from fossil fuel combustion and industrial activity (Isaksen et al., 1978; Fishman et al., 1985; Logan 1985). Ozone values are highest in winter and spring at other latitudes, in part because the stratospheric source is largest then (Levy et al., 1985). There is 35% more O_3 at 40°N than at 40°S, in the middle troposphere (Logan, 1985).

Concentrations of O_3 tend to be smaller in the tropics than in mid-latitudes, except in the dry season, when emissions of O_3 precursors from biomass burning provide a photochemical source (Delany et al., 1985; Crutzen et al., 1985; Logan and Kirchoff, 1986; Fishman et al., 1990). Ozone values during the southern spring over South America can reach almost as high values as found over the industrialized mid-latitudes in summer. Large regions of the tropical troposphere appear to be influenced by sources of O_3 from biomass burning (Fishman et al., 1990). Remote marine air and continental air during the wet season may provide a photochemical sink for O_3 in the tropics; mean surface concentrations as low as 4 - 12 ppbv have been measured (Liu et al., 1980; Oltsmans and Komhyr, 1986; Kirchoff, 1990).

1.7.1.2 Trends

Most long-term measurements of O_3 have been made at northern mid-latitudes, from surface sites and from balloons. Only sporadic data are available before the 1970s. A comparison of data obtained in Paris from 1876-1910 (Volz and Kley, 1988) with rural data from the present day from Europe and North America (Logan, 1985, 1989) suggests that surface O_3 has increased by a factor of 2 -3 on average; the increase is largest in summer, the factor then being 4 -6 (Figure 1.15). Ozone values in Europe in the 1970s appear to be about twice those found between 1930 and 1950 (Crutzen, 1988). Data from Europe suggest an increase of 1 - 2% per year from the mid 1950s to the early 1980s, with increases in winter and summer (Feister and Warmbt, 1987; Bojkov, 1988). Since the mid-1970s O_3 has increased by 0.8% per year at remote sites in Alaska and Hawaii; shown no annual trend at Samoa, but has decreased by 0.5% per year at the South Pole (Oltmans et al., 1988). Decreases of 1.8% per year are found at both Samoa and South Pole in summer. Trend data are lacking for tropical continental sites.

Ozonesonde data for northern mid-latitudes between 1965 and 1986 suggest that O_3 has increased by about 1% per year below 8 km, primarily over N. Europe and Japan (Angell and Korshover, 1983; Logan 1985; Tiao et al., 1986; WMO, 1989a,b), but there are no clear trends in the upper troposphere. By contrast, O_3 has decreased in the lower stratosphere (below 25 km), the crossover in the trend being near the tropopause. There is no trend in O_3 at the single sonde station at southern mid-latitudes, and long term sonde data are lacking in the tropics.

1.7.1.3 Relationships between ozone and its precursors

The concentration of tropospheric O_3 is dependent in a very non-linear manner on the atmospheric concentrations of its precursor gases, i.e., CO, CH_4, NMHC, and, in particular NO_x ($NO_x = NO + NO_2$). Nitrogen oxide concentrations and trends control changes in the concentration of O_3 (Dignon and Hameed, 1985). At low NO_x concentrations (where NO_x is less than 5 - 30 pptv; this threshold depends on the concentrations of O_3 and hydrocarbons) increases in CO, CH_4, and NMHC lead to a decrease in O_3, whereas at high NO_x concentrations increases in CO, CH_4, and NMHC lead to significant enhancements in O_3. Therefore, no simple relationship exists between increases in the precursor gases and changes in tropospheric O_3. Several model calculations have been performed to investigate the sensitivity of O_3 changes to changes in the precursor gases, both individually and collectively. All models that have attempted to simulate changes in O_3 during the past century have calculated increases in Northern Hemisphere O_3 by up to a factor of two, broadly consistent with observations, depending upon the assumptions made regarding the initial concentration, distribution, and changes in precursor gas concentrations, particularly NO_x.

Understanding the feedbacks among O_3 and its precursor gases is essential to understand tropospheric OH, which controls the atmospheric lifetimes of CH_4 and the NMHCs. The global concentration of OH, which determines the oxidizing capacity of the troposphere, can be either enhanced because of elevated levels of tropospheric O_3, NO_x or water vapour (associated with a global warming) or suppressed because of increases in CH_4, CO, and NMHC (Crutzen, 1987; Thompson et al., 1989). Prediction of regional and global trends in OH concentrations requires an understanding of regional emissions of CH_4, CO, NMHC and NO_x, as well as transport of O_3 between its source regions and the remote troposphere. One key point is that a continued increase in levels of CO would reduce the global concentration of OH because NO_x is too short-lived to counteract that effect over much of the globe. This would increase the atmospheric lifetime of CH_4.

1.7.2 Carbon Monoxide

1.7.2.1 Atmospheric distribution of carbon monoxide

The atmospheric concentration of CO exhibits significant spatial and temporal variability because of its short atmospheric lifetime (2 - 3 months). The short atmospheric lifetime, coupled with an inadequate monitoring network, means that the global spatial variability and long-term trends in CO are not well documented. The limited observational data base (Heidt et al. 1980; Dianov-Klokov and Yurganov, 1981; Seiler and Fishman, 1981; Seiler et al. 1984; Khalil and Rasmussen, 1984, 1988a; Fraser et al. 1986 a, c; Newell et al. 1989; Zander et al., 1989; Kirchoff and Marimho, 1989; Kirchoff et al., 1989) has demonstrated that the concentration of CO, (i) is about a factor of two greater in the Northern than in the Southern Hemisphere where the annual average is about 50 - 60 ppbv, (ii) increases with latitude in the northern hemisphere, (iii) exhibits strong seasonal variations in both hemispheres at mid to high latitudes, and (iv) decreases with altitude. CO appears to be increasing at about 1% per year in the northern hemisphere, but the evidence for increases in the southern hemisphere is ambiguous.

1.7.2.2 Sources and sinks for carbon monoxide

The total annual source of CO is about 2400 Tg CO, being about equally divided between direct anthropogenic (incomplete combustion of fossil fuels and biomass) and atmospheric (oxidation of natural and anthropogenic CH_4 and NMHC) sources (Logan et al. 1981; Cicerone, 1988). Atmospheric concentrations of CO may have increased in the northern

hemisphere because of the fossil fuel source, and because of changes in the rate of oxidation of CH_4, whose atmospheric concentration has increased since pre-industrial times. Fossil fuel sources of CO are presently decreasing in North America (EPA, 1989) and possibly in Europe, but may be increasing elsewhere.

The major removal process for atmospheric CO is reaction with OH (Logan et al. 1981). The observed seasonal variability in the southern hemisphere, distant from seasonally varying sources, can be explained by the seasonal variability in the concentration of tropospheric OH. Soils may provide a minor sink for CO (Conrad and Seiler, 1985).

extra space

1.7.3 Reactive Nitrogen Oxides

The key constituents of tropospheric NO_y, defined as the sum of all nitrogen oxide species except for N_2O, are NO_x, nitric acid (HNO_3), peroxyacetylnitrate (PAN: $CH_3CO_3NO_2$), and organic nitrates. Most primary sources of nitrogen oxides release NO_x (mainly NO); the other species are produced by photochemical reactions in the atmosphere. While the atmospheric lifetime of NO_x is short (about 1 day), the atmospheric lifetime of NO_y can range up to several weeks. Thus NO_y can transport nitrogen compounds away from source regions to more remote locations, where photolysis of HNO_3 and PAN, and thermal decomposition of PAN, can regenerate NO_x.

1.7.3.1 Atmospheric distribution of nitrogen oxides

The atmospheric concentrations of NO_x exhibit significant spatial and temporal variability, reflecting the complex distribution of sources and the short atmospheric lifetime. The near surface and free tropospheric concentrations of NO_x each vary by several orders of magnitude, highly influenced by the proximity of source regions. Near surface concentrations of NO_x range from as low as 0.001 ppbv in remote maritime air to as high as 10 ppbv in Europe and Eastern N. America (excluding urban areas), while free tropospheric concentrations range from 0.02 ppbv in remote regions to more than 5 ppbv over populated areas (Fehsenfeld et al., 1988).

The spatial inhomogeneity, coupled with a sparsity of measurements, means that the spatial and temporal distribution and long-term trends in NO_x and NO_y are not adequately documented, although reconstructed emissions inventories of NO_x suggest large increases throughout this century (Dignon and Hameed, 1989). Data from a Greenland ice core have shown that the concentration of nitrate ions (dissolved nitrate from HNO_3) remained constant from 10,000 years ago to about 1950, then doubled by the late 1970's, consistent with the increase in industrial emissions (Neftel et al. 1985b). Data from glacier ice in Switzerland indicates that nitrate ions increased by a factor of 4 -5 between 1900 and the 1970's in Western Europe (Wagenbach et al. 1988).

1.7.3.2 Sources and sinks of nitrogen oxides

The sources of atmospheric NO_x are about equally divided between anthropogenic (combustion of fossil fuels: 21 Tg N per year, and biomass burning: 2 - 5 Tg N per year), and natural (microbial processes in soils: 20 Tg N per year; lightning: 2 - 8 Tg N per year, and transport from the stratosphere: 1 Tg N per year) (Galbally, 1989). Emissions of NO_x (6.3 Tg N per year) from the combustion of fossil fuels have not increased in N. America since 1970 (EPA, 1989). Soil emissions of NO are stimulated by agricultural activity (e.g., addition of fertilizer, manure, etc.), hence, agricultural soil emissions may provide significant sources of NO_x in many areas.

The dominant removal processes for NO_x are (i) conversion to HNO_3, PAN, and organic nitrates by photochemical mechanisms, (ii) reactions involving NO_3 radicals, and possibly (iii) deposition of NO_2 on vegetation. The resulting NO_y species are then removed from the atmosphere by wet and dry deposition, or by conversion back to NO_x.

1.7.4 Non-Methane Hydrocarbons

1.7.4.1 Atmospheric distribution of non-methane hydrocarbons

The NMHC can be classified by atmospheric lifetime: (i) relatively long-lived (lifetimes > week) where the highest concentrations (up to 3 ppbv for ethane) are observed at middle to high northern latitudes; (ii) more reactive (lifetimes between half a day and one week) such as C_2 - C_5 alkenes whose concentrations exhibit significant temporal and latitudinal variability from <0.1ppbv in remote areas to a few ppbv close to source regions, and (iii) extremely short lived (lifetimes of hours) such as terpenes or isoprene whose local concentrations may reach about 10 ppbv very close to their sources. Trends in the atmospheric concentrations of NMHC have not been established due to a lack of measurements.

1.7.4.2 Sources and sinks for non-methane hydrocarbons

The oceans are a major source of NMHC, mainly alkenes. Estimates of the source strength of ethene and propene range from 26 Tg C per year (Bonsang et al., 1988) to as high as 100 Tg C per year (Penkett, 1982). Emissions of NMHC from terrestrial vegetation are dependent upon environmental factors as well as the type of vegetation. Isoprene is primarily emitted from deciduous plants, whereas conifer trees are primarily a source of terpenes. Isoprene and terpene emission rates are very large, about 500 Tg per year for each (Rasmussen and Khalil, 1988). The source strength of NMHC from anthropogenic activities such as biomass burning, solvents and fossil fuel combustion has been estimated to be about 100 Tg per year.

The dominant loss mechanism for most NMHC is rapid (much faster than CH_4) reaction with OH. The products of these reactions are capable of forming O_3 in the presence of NO_x.

1.7.5 Feedbacks Between Climate and the Methane / Non-Methane Hydrocarbon / Carbon Monoxide / Oxides of Nitrogen / Tropospheric Ozone System

There are numerous potentially important feedbacks between climate change and tropospheric O_3 and OH. Changes in cloud cover, precipitation, and circulation patterns, as well as changes in the biospheric source strengths of CH_4, CO, NMHC and NO_x, will induce changes in homogeneous and heterogeneous reactions controlling O_3 and OH. In addition, changes in stratospheric O_3 may induce changes in tropospheric processes, through changes in ultraviolet radiation. Stratospheric O_3 depletion is likely to increase tropospheric O_3 when the levels of CO, NO_x, and NMHC are high, but reduce it in regions of very low NO_x. The importance of these feedback processes remains to be determined.

1.7.6 Conclusions

Tropospheric O_3 is a greenhouse gas that is produced photochemically though a series of complex reactions involving CO, CH_4, NMHC and NO_x. Hence, the distribution and trends of tropospheric O_3 depend upon the distribution and trends of these gases whose atmospheric concentrations are changing.

The short atmospheric lifetimes of O_3 (several weeks), and many of its precursor gases, coupled with inadequate observational networks, leave their distributions and trends inadequately documented. Most data support positive trends of about 1% per year for O_3 below 8 km altitude in the Northern Hemisphere (consistent with positive trends in several of the precursor gases, especially NO_x, CH_4, and CO), and a similar trend for CO in the Northern Hemisphere, but not in the Southern Hemisphere. While there is no systematic series of data that allow quantitative estimates of trends in NMHC and NO_x to be made, their atmospheric concentrations are likely to have increased during the past few decades because of increased anthropogenic sources. The ice core records of nitrate levels provide indirect evidence for a Northern Hemisphere increase in atmospheric NO_x.

1.8 AEROSOL PARTICLES

1.8.1 Concentrations and Trends of Aerosol Particles in the Troposphere

Aerosol particles play an important role in the climate system because of their direct interaction (absorption and scattering) with solar and terrestrial radiation, as well as through their influence on cloud processes and thereby, indirectly, on radiative fluxes. These processes are discussed in more detail in Sections 2.3.2 and 2.3.3. Two separate issues should be identified. The first is the effect of increasing or decreasing anthropogenic emissions of aerosol particles and their precursors in regions impacted by these emissions. The second is the role of feedback processes linking climate change and natural (biological) production of particles in unpolluted regions, especially over the oceans (cf. Section 10.8.3).

Total suspended particulate matter in air varies from less than 1 $\mu g\ m^{-3}$ over polar ice caps or in the free mid ocean troposphere to 1 $mg\ m^{-3}$ in desert dust outbreaks or in dense plumes from e.g., forest fires. In a typical sample of continental air mineral dust, sulphuric acid, ammonium sulphate as well as organic material and elemental carbon (soot) may be found both as pure or mixed particles. Most of the soluble particles become solution droplets at relative humidities above 80%; thus the radiative properties of aerosol particles even vary with relative humidity at constant dry aerosol mass.

A large part of the aerosol mass in submicron size particles is derived from gas-to-particle conversion through photochemical processes involving gaseous sulphur and hydrocarbon compounds. Such conversion may take place through photochemical processes involving the oxidation of sulphur dioxide (SO_2) and other sulphur gases to sulphuric acid (H_2SO_4) by reaction with OH. The H_2SO_4 so formed, having a low equilibrium vapour pressure, immediately condenses onto existing aerosol particles or forms new ones. Transformation to sulphuric acid and sulphate also takes place in cloud droplets, the majority of which eventually evaporate leaving the sulphate in the aerosol phase. Trends in the emission of these gaseous precursors, especially the sulphur gases, are therefore of great importance for the regional aerosol burden and thereby potentially for climate.

Large quantities of aerosol particles are also emitted from the burning of savannas and forests in tropical regions. The directly emitted particles consist largely of carbonaceous materials including black carbon (soot) (Andreae et al., 1988). In addition, particles are formed from precursor gases like SO_2 and hydrocarbons emitted by fires.

The average tropospheric life time of aerosol particles, and of their precursor gases, is of the order of only days or weeks. This is much shorter than the lifetime of most greenhouse gases. It implies that the atmospheric loading at any one time reflects the emissions that have taken place during the past few weeks only. No long-term accumulation in the troposphere is thus possible and any reduction in anthropogenic emissions will immediately result in a corresponding reduction in tropospheric concentrations. The short lifetime also implies large spatial and temporal variability in the concentrations of aerosol particles.

It has been established from analyses of Greenland ice cores that the amounts of sulphate, nitrate and trace metals, derived mainly from atmospheric aerosols, have been increasing since industrialisation began (Neftel et al., 1985 b; Mayewsky et al., 1986). However, there are almost no long-term, continuous direct observations of aerosol parameters in the atmosphere outside urban and industrial areas (Charlson, 1988). Indirect evidence from visibility observations indicates that the concentration of submicron aerosols over much of the eastern part of the U.S. has increased during the period 1948-1978 (Husar et al., 1981).

Another example of a trend analysis of atmospheric aerosols is due to Winkler and Kaminski (1988), who concluded that submicrometer aerosol mass outside Hamburg has increased by a factor of nearly two between 1976 and 1988 due to long range transport from industrialized centres in the region.

The hypothesis by Charlson et al. (1987) of a connection between climate and phytoplankton activity in ocean surface waters is based on the role played by soluble aerosol particles in determining the microphysical properties of clouds. The proposed climate-phytoplankton feedback rests on the facts that cloud condensation nucleus (CCN) concentrations in air are low over oceans far from land, that the CCN available in clean maritime air are composed almost totally of sulphate particles, and that this sulphur originates almost entirely from emissions of reduced sulphur gases (principally dimethylsulphide (DMS)) from the ocean surface. There is a significant non-linearity in the effect on cloud microphysics of given changes in CCN concentration, depending on the starting CCN concentration characteristics of clean oceanic air.

There is abundant evidence in the literature to confirm the role played by CCN concentration in determining cloud droplet size distribution. However, at this stage neither the sign nor magnitude of the proposed climate feedback can be quantitatively estimated, though preliminary calculations based on plausible scenarios indicate that this hypothesis merits careful consideration. Preliminary attempts to test this hypothesis using existing historical data of various types have been inadequate and have yielded only equivocal conclusions.

1.8.2 The Atmospheric Sulphur Budget

Current estimates of the global sulphur cycle show that anthropogenic emissions of SO_2 are likely to be at least as large as natural emissions of volatile sulphur species, cf. Table 5 (based essentially on Andreae, 1989). Within the industrialized regions of Europe and North America, anthropogenic emissions dominate over natural emissions by about a factor of ten or even more (Galloway et al., 1984; Rodhe, 1976). The anthropogenic SO_2 emissions have increased from less than 3 TgS per year globally in 1860, 15 in 1900, 40 in 1940 and about 80 in 1980 (Ryaboshapko, 1983). It is evident from these numbers that the sulphur fluxes through the atmosphere have increased very substantially during the last century, especially in the Northern Hemisphere. During the past decade the anthropogenic sulphur emissions in North America and parts of Europe have started to decline.

TABLE 5

Estimates of global emission to the atmosphere of gaseous sulphur compounds †

Source	Annual Flux (TgS)
Anthropogenic (mainly SO_2 from fossil fuel combustion)	80
Biomass burning (SO_2)	7
Oceans (DMS)	40
Soils and plants (H_2S, DMS)	10
Volcanoes (H_2S, SO_2)	10
Total	147

† The uncertainty ranges are estimated to be about 30% for the anthropogenic flux and a factor of two for the natural fluxes.

Small amounts of carbonyl sulphide (COS) are also emitted into the atmosphere. They do not significantly affect the sulphur balance of the troposphere but they are important in maintaining an aerosol layer in the stratosphere.

Because of the limited atmospheric lifetime of most sulphur compounds, the augmentation of the sulphur concentrations brought about by industrialization is not evenly distributed around the globe. This is illustrated by Figure 1.16, which shows an estimate of how much more aerosol sulphate there is at present in the lower atmosphere (900 hPa level) than in the pre-industrial situation (Langner and Rodhe, 1990). Over the most polluted regions of Europe and North America the sulphate levels have gone up by more than a factor of 10. Smaller increases have occurred over large parts of the oceans.

1.8.3 Aerosol Particles in the Stratosphere

The vertical profile of aerosol particle concentration normally exhibits a marked decline up through the troposphere followed by a secondary maximum in the lower stratosphere at around 20 km. The stratospheric aerosol layer is maintained by an upward flux of gaseous precursors, mainly carbonyl sulphide (COS). Concentrations may be greatly enhanced over large areas for a few years following large volcanic eruptions, such as El Chichon in 1982. No significant trends have been detected in the global background aerosol layer in the stratosphere during periods of low volcanic activity (WMO, 1989a). The potential impact on climate of stratospheric aerosols is discussed in Section 2.3.2.

1.8.4 Conclusions

Aerosol particles have a lifetime of at most a few weeks in the troposphere and occur in highly variable concentrations. A large proportion of the particles which influence cloud processes and for the radiative balance, are derived from gaseous sulphur emissions. These emissions have more than doubled globally, causing a large increase in the concentration of aerosol sulphate especially over and around the industrialized regions in Europe and North America. If anthropogenic sulphur emissions are indeed a major contributor to cloud condensation nuclei concentrations on a global scale, then any climate prediction must take account of future trends in regional and global anthropogenic sulphur emission, which may be quite different from those of the greenhouse gases.

Aerosol particles derived from natural (biological) emissions may contribute in important ways to climate feedback processes. During a few years following major volcanic eruptions the concentration of aerosol particles can be greatly enhanced.

Section 1
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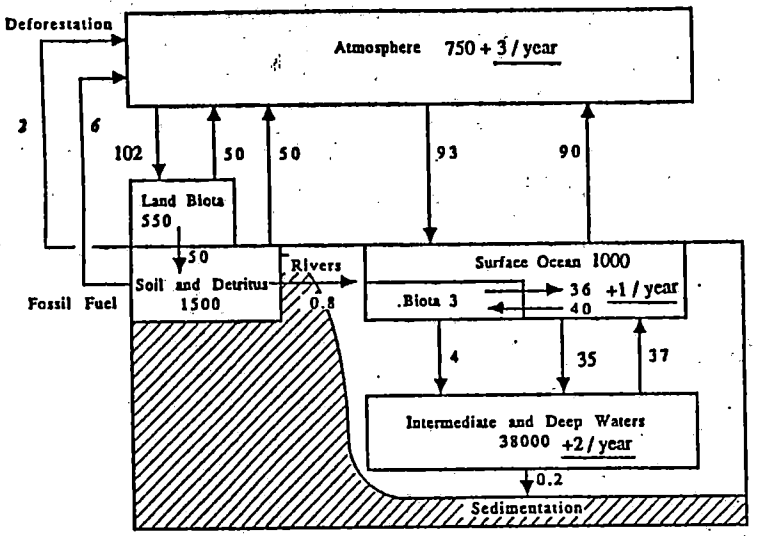

Figure 1: Global carbon reservoirs and fluxes. The numbers apply for the present-day situation and represent typical literature values. Fluxes, e.g. between atmosphere and surface ocean, are gross annual exchanges. Numbers underlined indicate net annual CO_2 accumulation due to human action. Units are gigatons of carbon (GtC; 1Gt = 10^9 metric tons = 10^{12}kg) for reservoir sizes and GtC yr^{-1} for fluxes. More details and discussions are found in several reviews (Sundquist, 1985; Trabalka, 1985; Bolin, 1986; Siegenthaler, 1986).

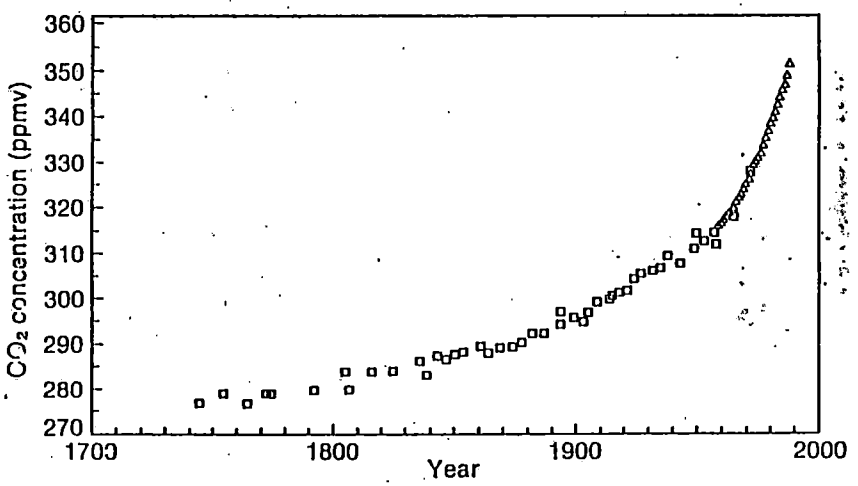

Figure 3: Atmospheric CO_2 increase in the past 250 years, as indicated by measurements on air trapped in ice from Siple Station, Antarctica (squares; Neftel et al., 1985a; Friedli et al., 1986) and by direct atmospheric measurements at Mauna Loa, Hawaii (crosses; Keeling et al., 1989a).

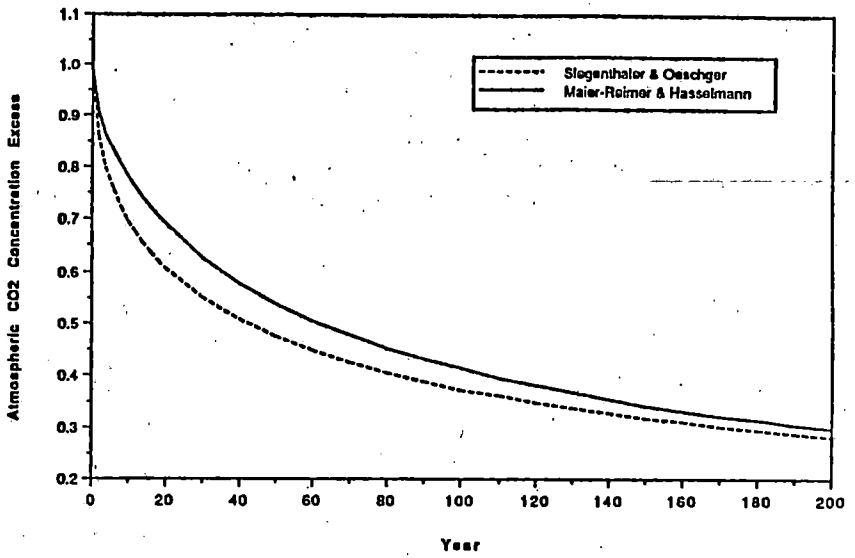

Figure 2: Atmospheric CO_2 concentration excess after a pulse input at time 0 (initially doubling the atmospheric CO_2 concentration), as calculated with two ocean-atmosphere models. Solid line: 3-dimensional ocean-circulation model of Maier-Reimer and Hasselmann (1987), dashed line: 1-dimensional box-diffusion model of Siegenthaler and Oeschger, 1987). The adjustment towards a new equilibrium does not follow an exponential curve; it is very fast during the first decade, then slows down more and more. The concentration excess does not go to zero; after a long time, a new equilibrium partitioning between atmosphere and ocean will be reached, with about 15 percent of the input residing in the atmosphere.

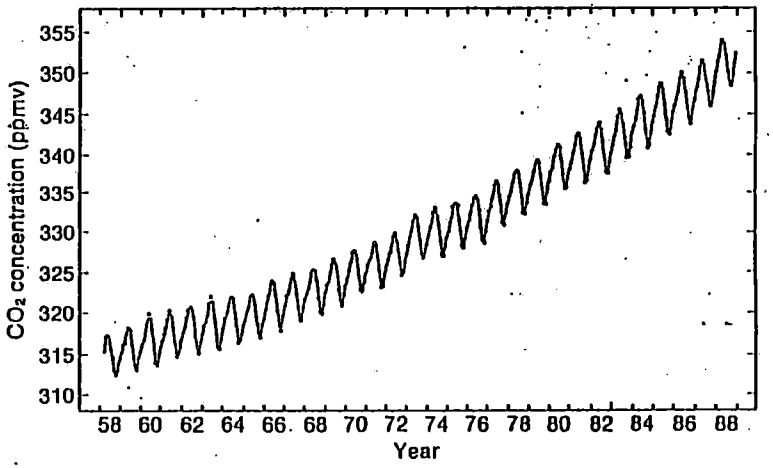

Figure 4: Monthly average CO_2 concentration in parts per million of dry air, observed continuously at Mauna Loa, Hawaii (Keeling et al., 1989a). The seasonal variations are due primarily to the withdrawal and production of CO_2 by the terrestrial biota.

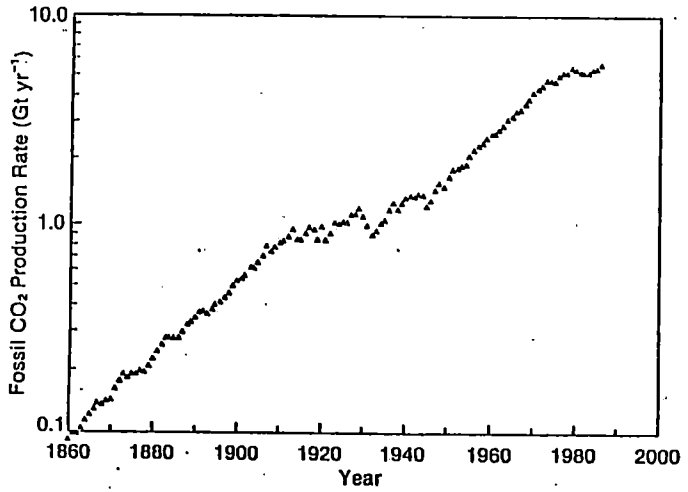

Figure 5: Global annual emissions of CO_2 from fossil fuel combustion and cement manufacturing, expressed in GtC yr^{-1} (Rotty and Marland, 1986; Marland, 1989). The average rate of increase in emissions between 1860 and 1910 and between 1950 and 1970 is about 4% per year.

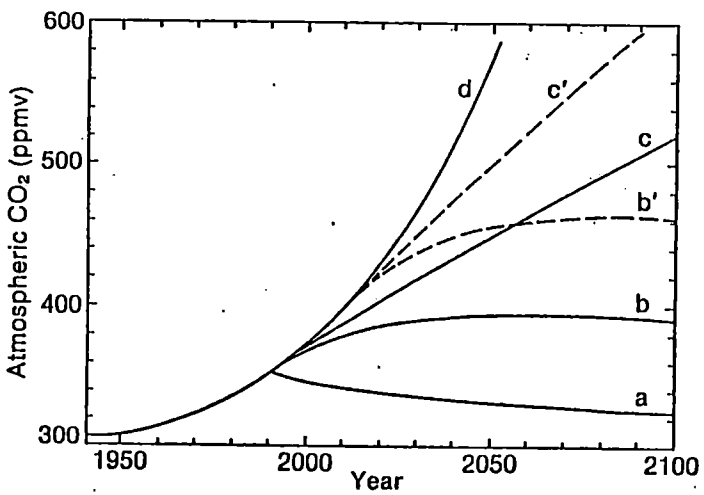

Figure 7: Future atmospheric CO_2 concentrations as simulated by means of a box-diffusion carbon cycle model (Enting and Pearman, 1982, 1987) for the following scenarios: a) - d): anthropogenic CO_2 production rate p prescribed after 1990 as follows: a) p = 0; b) p decreasing by 2% per year; c) p = constant; d) p increasing at 2% per year. Scenarios b') and c'): p grows by 2% per year from 1990-2010, then decreases by 2% per year (b') or is constant (c'). Before 1990, the concentrations are those observed (cf. Figure 3), and the production rate was calculated by to fit the observed concentrations.

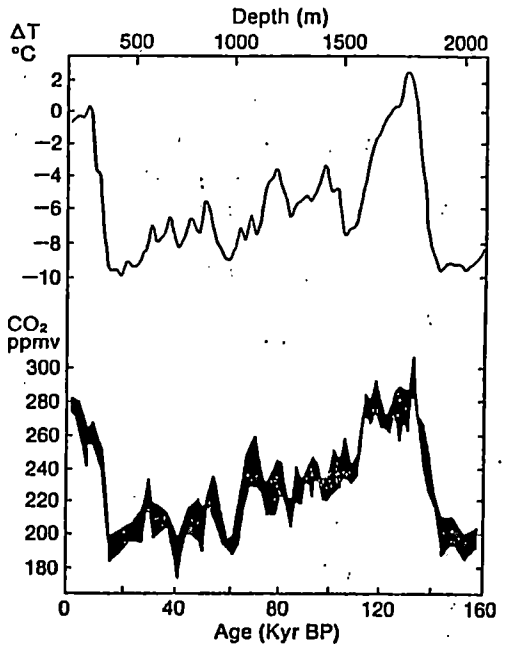

Figure 6: CO_2 concentrations (bottom) and estimated temperature changes (top) during the past 160,000 years, as determined on the ice core from Vostok, Antarctica (Barnola et al., 1987). Temperature changes were estimated based on the measured deuterium concentrations.

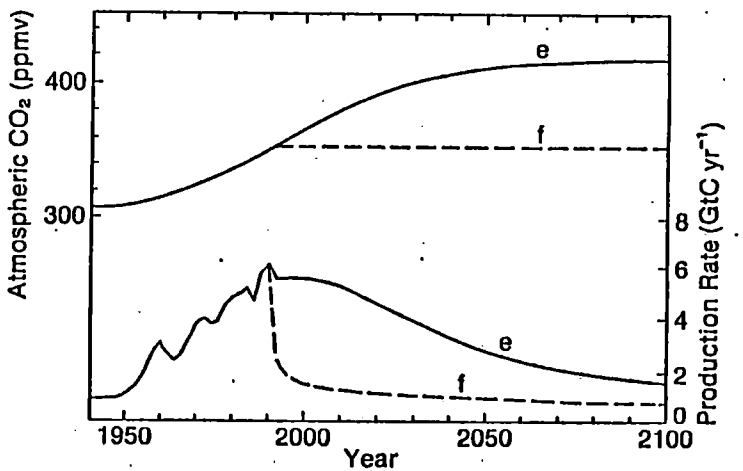

Figure 8: Future CO_2 production rates calculated by means of a box-diffusion carbon cycle model (Enting and Pearman, 1982, 1987) so as to yield the prescribed atmospheric CO_2 concentrations after 1990. e) concentration increasing steadily (logistic function of time) to 420 ppmv. f) concentration constant after 1990.

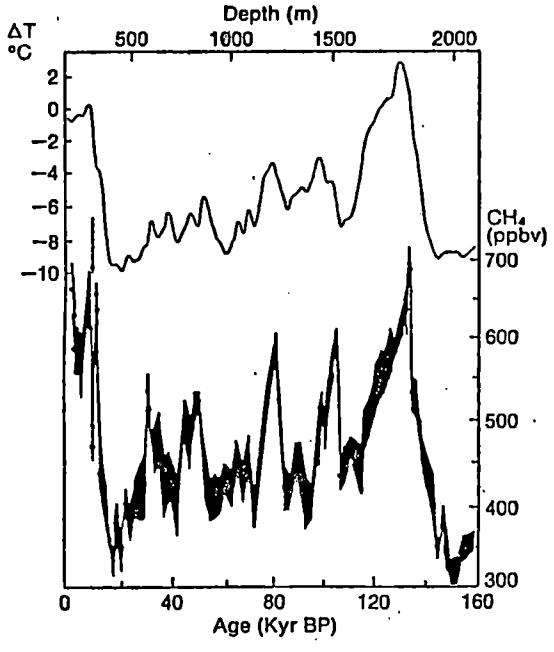

Figure 9: Methane concentrations (bottom) and estimated temperature changes (top) during the past 160,000 years as determined on the ice core from Vostok, Antarctica (Chappelaz et al., 1990). Temperature changes were estimated based on the measured deuterium concentrations.

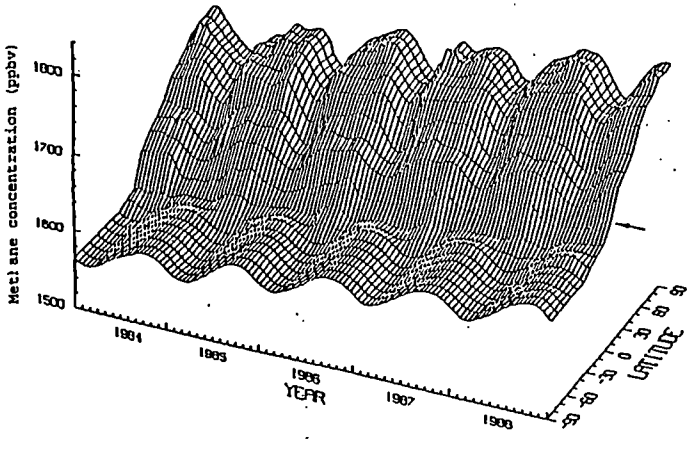

Figure 11: The global distribution, seasonality, and trend of methane from the GMCC network (Steele et al., 1987, and unpublished data)

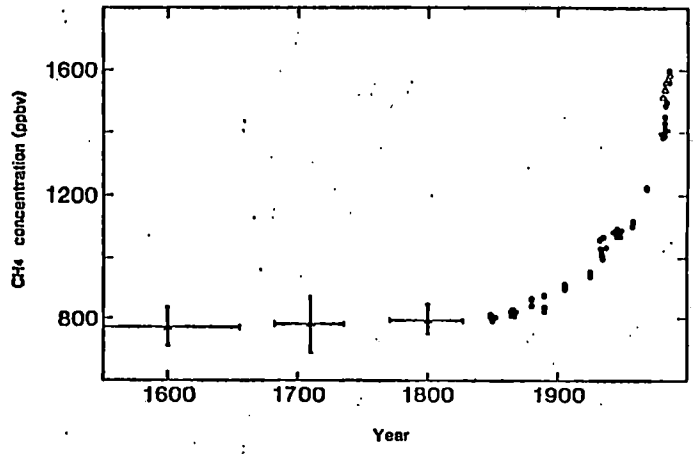

Figure 10: Atmospheric methane variations in the past few centuries measured from air in dated ice cores (Etheridge et al., 1988; Pearman and Fraser, 1989).

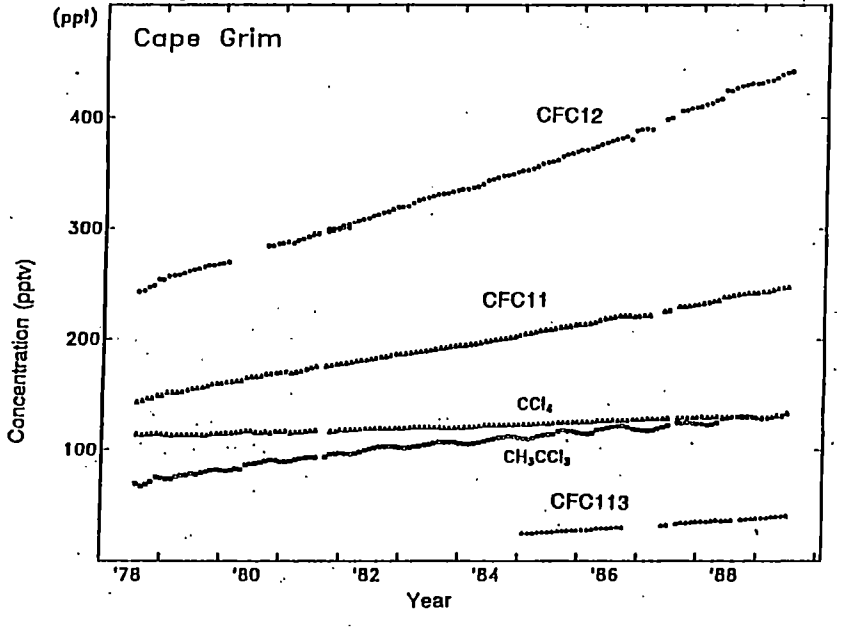

Figure 12: Halocarbon concentrations measured at Cape Grim, Tasmania during the period 1978-1989 (Fraser and Derek, 1989, and unpublished data).

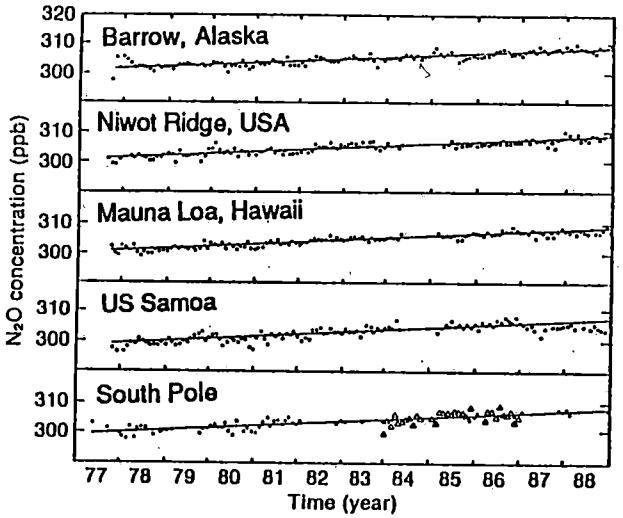

Figure 13: Atmospheric measurements of nitrous oxide from the NOAA/GMCC network (Elkins and Rossen, 1989).

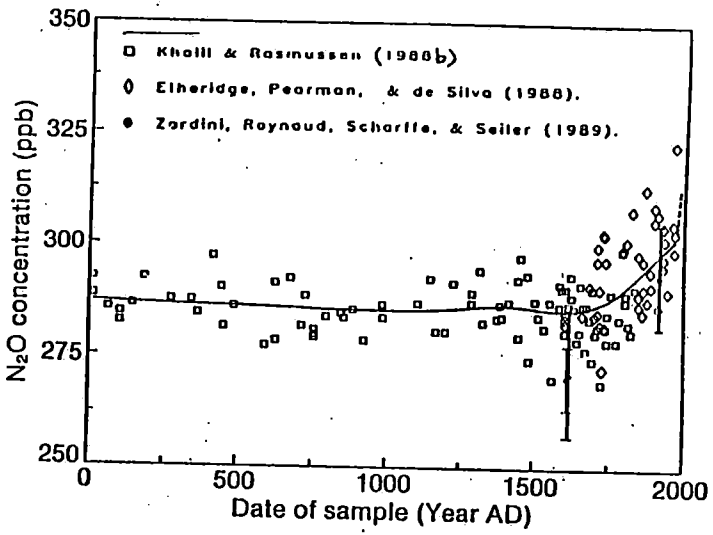

Figure 14: Nitrous oxide measurements from ice-core samples.

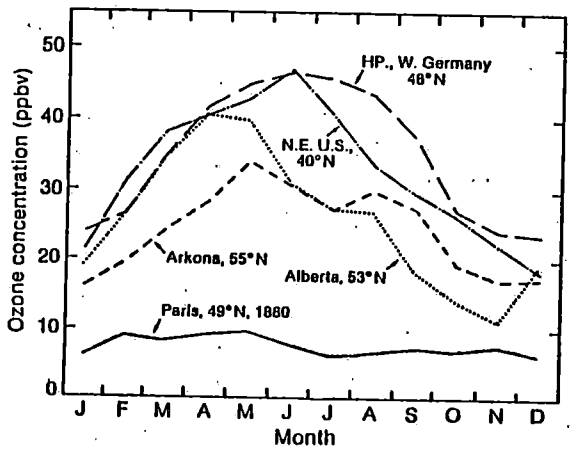

Figure 15: The seasonal variation of surface ozone. The solid line shows data from Montsouris, France, for 1876-86 (Volz and Kley, 1988). All other data are from the 1970s and 1980s: dashed line, Arkona, GDR (Feister and Warmbt, 1987); dotted line, Ellerslie, Alberta, Canada (Angle and Sandlu, 1986); dot-dash line, average of eight rural sites in the northeastern U.S., the SURE sites (Logan, 1988); long dashed line, Hohenpeissenberg, FRG (Logan, 1985). All the recent data are shown as monthly means of daily average values.

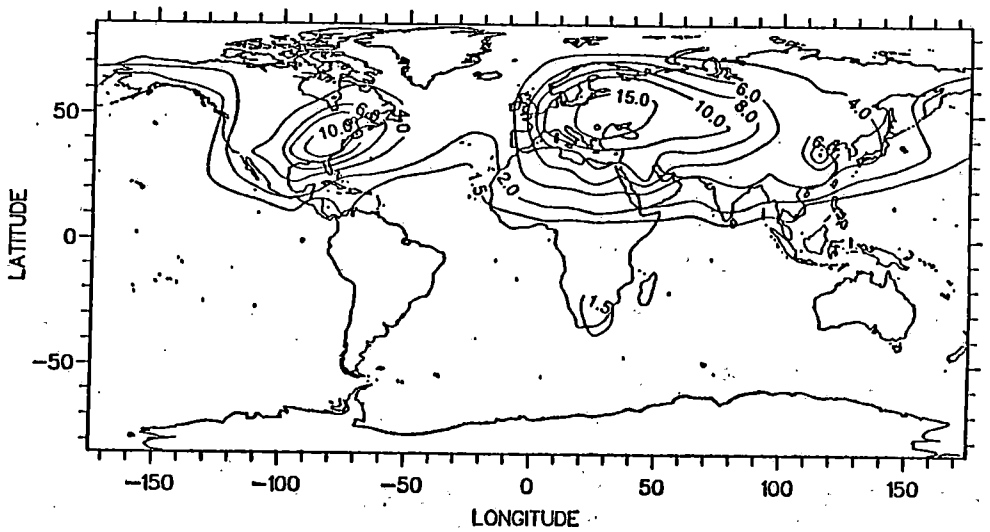

Figure 16: Simulated concentration of sulphate at 900 hPa: Ratio of concentrations based on total emissions (natural plus anthropogenic) divided by concentrations based on natural emissions, in July (Langner and Rodhe, 1990).

THE WHITE HOUSE

WASHINGTON

May 1, 1990

Global warming

MEMORANDUM FOR JAMES A. BAKER III
NICHOLAS F. BRADY
JOHN H. SUNUNU
BRENT SCOWCROFT
RICHARD G. DARMAN
ROGER B. PORTER
WILLIAM K. REILLY

FROM: DAVID Q. BATES, JR.

SUBJECT: Meeting on Financial Assistance for the Montreal Protocol

The final rounds of negotiations on the Montreal Protocol will occur in May and June. Decisions regarding U.S. positions, particularly with respect to financial mechanisms, are needed before the Geneva preparatory meeting, which begins May 9.

A meeting will be held in Governor Sununu's office at 10:00 A.M., on Wednesday, May 2, to consider financial mechanisms for the Montreal Protocol. The attached paper provides background and identifies options for discussion at that meeting.

Protocol Signed in '87.

Withdrawal/Redaction Sheet
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Document No. and Type	Subject/Title of Document	Date	Restriction	Class.
01. Paper	Financial Assistance for the Montreal Protocol (6 pp.)	5/1/90	P/5	

Collection:

Record Group: Bush Presidential Records
Office: Chief of Staff, White House Office of
Series: Sununu, John, Files
Subseries: Issues Files
WHORM Cat.:
File Location: 1990 Global Warming (2 of 2) [3]

Open on Expiration of PRA
(Document Follows)
By QL (NLGB) on 10/28/05

Date Closed:	12/17/2004	**OA/ID Number:**	29158-003
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Re-review Case #:	2005-0426-S	**Appeal Disposition:**	
P-2/P-5 Review Case #:		**Disposition Date:**	
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(b)(8) Release would disclose information concerning the regulation of financial institutions [(b)(8) of the FOIA]
(b)(9) Release would disclose geological or geophysical information

May 1, 1990

FINANCIAL ASSISTANCE FOR THE MONTREAL PROTOCOL

ISSUE

Should the United States support the establishment of a new financial assistance mechanism to aid developing countries in phasing out chlorofluorocarbon (CFC) production?

DISCUSSION

The issue is important both because of its specific application to commitments made within the framework of the Montreal Protocol and because of its precedential nature. What is done here will likely become a template for expectations in other environmental conventions and protocols like the Basel Convention on Waste Export and a Global Climate Change Convention.

1. The 1987 Montreal Protocol requires that signatory nations reduce their CFC production 50% by 1998.

A June 20-30 meeting of the Parties to the Protocol will consider amendments to cover certain outstanding issues, including the financing question, newly controlled substances, and whether to agree to a phase-out of CFCs by the year 2000. A preparatory meeting on May 9-11 will focus on financial assistance.

2. There is general agreement among the Parties that a financial assistance mechanism is needed to encourage developing nations to sign and adhere to the Protocol.

Twenty-three of the fifty-two nations that have ratified the Protocol are developing countries. Developing countries together account for only about 10% of worldwide CFC production, but without controls their production could, in the future, offset the CFC reductions achieved in the industrialized countries. Three countries that have not yet signed -- India, China, and Brazil -- account for about 90% of all CFC produced by the developing world.

Developing countries argue that industrialized countries should subsidize their net additional cost of phasing out CFC production because:

- Industrialized nations created the problem by allowing their economies to prosper using cheap but harmful CFCs;

- o The cost to developing countries of phasing out CFCs is much larger than the benefit to them; and

- o Developing countries have more immediate problems to worry about.

3. U.S. support has been limited.

To date, the United States has agreed only to support a clearinghouse to: 1) foster technology transfer between donor and recipient nations, and 2) conduct nation-specific needs assessments. The clearinghouse would be funded through voluntary contributions. We have also agreed to explore the need for a financial mechanism to aid developing nations in implementing the CFC phaseout.

4. The long-term costs to developing nations of phasing out CFCs are largely unknown.

A study conducted by the McKinsey Co. for the United Nations Environmental Programme concluded that these costs would be $400 million per year over ten years. Because of the many uncertainties, EPA suggests planning on the basis of $100 million over a three-year timeframe.

5. There is general agreement among Parties that, if a new financial mechanism is created, it should be placed within the World Bank.

The World Bank is already active on environmental issues. The Bank estimates that about a third of its $5.7 billion in projects approved in 1989 contained a significant environmental component. Two main types of financing mechanisms have been proposed.

- o The Green Fund. The World Bank (supported by France and Germany) has proposed a $400-800 million fund to provide concessional resources for a broad range of environmental problems besides ozone depletion, including global climate change. The U.S. has thus far opposed the Green Fund as inadequately justified and possibly premature.

- o A Fund Limited to CFCs. The EPA recommends a mechanism that would be managed by the World Bank, ~~but remain under the authority of the Montreal Parties~~. A nation's in-kind contributions ~~and bilateral~~ aid could be counted as substitute for other contributions. Assuming a fund of $100 million and contributions based on the UN scale, the U.S. share would be $25 million.

6. The voting process for the June meeting makes it difficult for the U.S. to avoid taking a position.

At the June meeting, all amendments to the Protocol will be considered as a single decision. This is because the amendments are interdependent. As a consequence, should the U.S. decline to accept a negotiated proposal on any part of the comprehensive amendment (such as financial measures), we would not be able to become party to the amended Protocol. This could expose the U.S. to international criticism and possibly trade sanctions.

OPTIONS

Option 1: Retain current U.S. position.

- Provide financial assistance on a strictly voluntary bilateral basis; do not commit to an increase in financial aid.
- Continue to study the need for a new financial mechanism.
- Establish a clearinghouse to provide technical assistance to Parties and to conduct studies.

Advantages

- Provides the U.S. maximum flexibility in deciding on the level of expenditures, the identity of aid recipients, and how our money would be spent.
- Avoids a bad precedent for international agreements. The U.S. will be signalling that cooperation in implementing the Montreal Protocol or any future agreements will not be conditioned on whether or to what extent others pay.
- Retains leverage over the developing nations. They will have no incentive to accommodate us on other issues if their costs are automatically covered.
- Does not preclude the U.S. from implementing a CFC phaseout through the EPA regulatory process. This would blunt any criticism of the U.S. for not ratifying the amended Protocol and also avoid Protocol trade sanctions.
- Still gives us some opportunity to shape the parameters of a new financial mechanism if the Parties agree in June to establish one. At the June meeting, the

Parties will only be expected to agree to <u>principles for</u> a new financial mechanism.

<u>Disadvantages</u>

- Without a financial assistance mechanism, key developing nations, such as China, India, and Brazil, may not sign the Protocol. Unless these nations join, their increasing CFC production will eventually overwhelm reductions made by signatory countries.

- If this is a bottom-line position, and the Parties agree in June to support a new financial mechanism, the U.S. cannot become a Party to the amended Montreal Protocol.

<u>Option 2</u>: Agree that financial assistance is desirable, but use existing mechanisms to provide it.

- Agree to pressure multilateral development banks to assign a higher priority to projects for reducing CFC production, and to assign a higher priority to CFC-related projects in U.S. bilateral aid.

- Do not commit to an increase in financial assistance and do not earmark funds specifically for CFC-related projects.

<u>Advantages</u>

- Avoids establishing earmarked environmental funding in each international aid institution and avoids the commitment of additional funds.

- Would encourage prioritization of environmental projects and the integration of environmental and other considerations in lending decisions.

<u>Disadvantages</u>

- Would require the concurrence of lending institutions. They would likely oppose this position without <u>additional</u> funding.

<u>Option 3</u>: New financial mechanism within the World Bank to pay "agreed to" incremental costs to developing nations. As proposed by EPA, would include:

- Voluntary contributions, but on UN scale of assessment, meaning that the expected U.S. contribution will be 25 percent.

- Three-year funding period, with total of $100M in additional funds suggested for first three years. Allow substitution of bilateral for multilateral aid.

Advantages

- If accepted by the Parties in June, would allow the U.S. to ratify the amended Protocol, fulfilling the President's commitment to make the Protocol work.

- Provides greater assurance that developing nations will participate in the CFC phaseout, thus reducing atmospheric chlorine levels.

- While more costly than Options 1 or 2, the costs will be low, especially in comparison to the $5 billion in expected revenues the U.S. government will collect from the CFC production tax included in last year's budget reconciliation legislation.

- Such a financial mechanism would not necessarily set a precedent for future international negotiations, especially a climate change agreement. There is currently little aid for CFC reductions, whereas there are already aid programs that act to reduce carbon dioxide emissions.

Disadvantages

- Compared to Options 1 and 2, limits U.S. flexibility in deciding on the level of expenditures, the identify of aid recipients, and how our funds would be spent.

- Does not include a provision to assure that voting on overall assistance levels is controlled by the industrialized nations.

- Whether or not a precedent is intended, establishing a financial aid mechanism here would start the U.S. down a slippery slope of providing similar aid under other agreements. The cost to the U.S. of a financial mechanism to cover carbon dioxide reductions under a climate change protocol would be enormous.

- "Agreed to" incremental costs have not been defined and may be difficult to limit in future years.

Option 3 1/2

Option 4: Endorse the "green fund" concept of integrating all existing and future environmental aid programs into a single multilateral fund.

→ Look @ Prospectus

- Makes no immediate commitment to increase funding.
- Would be coordinated closely with developmental aid programs.
- Would likely be established within existing institutions such as the World Bank.

Advantages

- Avoids seriatim creation of new funds and funding mechanisms for each international environmental agreement.
- Encourages prioritization of environmental projects and coordination with economic development.
- Utilizes existing institutions, thus avoiding a proliferation of funding mechanisms

Disadvantages

- Other Parties may eventually vote to add objectionable amendments, thus placing the U.S. in the position of opposing its own proposal.
- Has potential to be the highest cost option and longest term commitment.
- Since the fund would cover many projects and international agreements, could result in dilution of resources and weakening of U.S. environmental policy priorities.

CONSORTIUM of SOCIAL SCIENCE ASSOCIATIONS

1522 K STREET, NW, SUITE 836, WASHINGTON, D.C. 20005 • [202] 842-3525 • FAX [202] 842-2788

April 20, 1990

file

Dr. Michael Boskin
Chairman
Council of Economic Advisers
Old Executive Office Building
Washington, DC 20500

Dear Dr. Boskin:

Just a short note to express our deep appreciation for your calling attention to the importance of economic research to the problems of global environmental change.

Your recent speech to the White Conference on Science and Econmics Research Related to Global Change will go a long way to convincing skeptics about the importance of social science contributions to the difficult problems this nation and the rest of the world face in this arena.

We also appreciate your efforts to improve the quality of economic statistics.

Thank you again for your words of support. I look forward to seeing you soon.

Sincerely,

Howard J. Silver

Howard J. Silver, Ph.D.
Executive Director

GENERAL MOTORS CORPORATION
GENERAL MOTORS BUILDING
DETROIT, MICHIGAN 48202

ROGER B. SMITH
CHAIRMAN

May 23, 1989

The Honorable John Sununu
Chief of Staff
The White House
Washington, D.C. 20500

Dear John:

As we discussed, the very complex issue of global warming is receiving increasing attention. The knowledge we now have about this issue is sufficiently disturbing to warrant a concerted national and international effort to get the facts necessary to enable governments to make sound judgments about the public policies that should be adopted.

The greenhouse effect is well understood. However, there are many important uncertainties about global warming including the ways oceans, clouds and other conditions affect the impact of carbon dioxide.

Whether actions should be taken now, before the important uncertainties are resolved, is not a question of science but a matter of judgment. To make sound judgments, it is essential to have an adequate appreciation of the costs and benefits of actions being proposed and the relationship of those actions to the international nature of this issue.

Some costs are unquantifiable such as impact on freedom of mobility, relief from heavy labor or protection from harsh climates. Others, such as job loss are quite quantifiable. People who might lose their jobs as a result of some regulatory program no doubt would like to have the uncertainties of the global warming issue addressed before they make that sacrifice.

Proper perspective is essential to assure regulatory programs are soundly based. Not to raise the question of costs is a disservice to those adversely affected.

Carbon dioxide accounts for about 50 percent of any forecast global warming. U.S. motor vehicles account for about 5.5 percent of world-wide man-produced carbon dioxide. Any increase in vehicle fuel efficiency, which would not have full impact for 10 or so years while the existing fleet is replaced, would have only a small fraction of an impact on the greenhouse effect.

This underscores the need for perspective in regulatory programs. One of those, the CAFE program, does not save fuel, but does disadvantage full line-U.S. manufacturers.

We support a significant increase in research; an international approach to the issue and the discussion of a possible "greenhouse" or carbon fee. We also support new solutions such as alternative fuels and safe nuclear energy.

We are carrying this message to Congress and would appreciate the efforts of the Administration to lead in this positive approach to this issue. We would welcome the opportunity to discuss this matter at greater length.

Sincerely,

Roger

Roger B. Smith

101ST CONGRESS
1ST SESSION

S. 324

To establish a national energy policy to reduce global warming, and for other purposes.

IN THE SENATE OF THE UNITED STATES

FEBRUARY 2 (legislative day, JANUARY 3), 1989

Mr. WIRTH (for himself, Mr. BUMPERS, Mr. GORE, Mr. CRANSTON, Mr. HEINZ, Mr. FOWLER, Mr. PELL, Mr. BINGAMAN, Mr. LEAHY, Mr. MATSUNAGA, Mr. HOLLINGS, Mr. INOUYE, Mr. ADAMS, Mr. BREAUX, Mr. SANFORD, Mr. DASCHLE, Mr. JEFFORDS, Mr. D'AMATO, Mr. DODD, Ms. MIKULSKI, Mr. GORTON, Mr. SARBANES, Mr. MOYNIHAN, Mr. LIEBERMAN, Mr. SIMON, Mrs. KASSEBAUM, Mr. DECONCINI, Mr. SPECTER, Mr. BRYAN, Mr. BOSCHWITZ, and Mr. RIEGLE) introduced the following bill; which was read twice and referred to the Committee on Energy and Natural Resources

---

A BILL

To establish a national energy policy to reduce global warming, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE AND TABLE OF CONTENTS

SECTION 1. SHORT TITLE.—(a) This Act may be referred to as the "National Energy Policy Act of 1989".

(b) TABLE OF CONTENTS.—

FINDINGS AND PURPOSES

SEC. 2. (a) FINDINGS.—The Congress finds that—

(1) the Earth's atmosphere is being altered by the generation of carbon dioxide and other trace gases (methane, tropospheric ozone, chlorofluorocarbons, and nitrous oxide);

(2) these gases are, in large part, the result of human activities including the widespread use of fossil fuels, population growth, deforestation, agricultural practices, and use of chlorofluorocarbons;

(3) current scientific understanding predicts that continued alteration of the global atmosphere will cause widespread temperature extremes and sea level rise which will, in turn, have serious implications for

the Earth's ecosystems, agricultural production, water supply, human health, wetlands, and climate;

(4) shifts in regional precipitation, growing seasons, sea level, and possible increases in the severity and frequency of storms and hurricanes will cause major disruptions in the economic, political, social, and ecological systems of all nations;

(5) energy and natural resources policies must be designed to reduce carbon dioxide and trace gas generation including reduction in the combustion of fossil fuels through energy efficiency, fuel switching, and conservation; use of safe nuclear, innovative clean coal and renewable energy technologies; and reforestation policies;

(6) in the near-term, increasing the Nation's energy efficiency can make the largest and least costly contribution to reducing carbon dioxide and trace gas production and reliance on imported oil;

(7) development of affordable solar energy technologies, particularly solar photovoltaics, promises to provide major new means of energy production and use that can reduce dependence on fossil fuels;

(8) policies are urgently needed for reducing deforestation and increasing reforestation; and for promoting economic growth and development through sus-

tainable development at the national and international levels;

(9) in so far as some degree of further atmospheric change is inevitable, the Federal Government must take immediate steps to devise and implement adaptive strategies for coping with the environmental and economic impacts of climate change; and

(10) adoption and implementation of these energy and natural resources policies will help promote national and international economic growth and development, achieve a secure energy supply, and protect the national and global environment.

(b) PURPOSES.—The overall purpose of this Act is to establish a national energy policy that will reduce generation of carbon dioxide and trace gases as quickly as is feasible in order to reduce to the maximum extent practicable, risks associated with an atmospheric warming and global climate change. The specific purposes are—

(1) to require the Secretary of Energy, hereinafter referred to as the "Secretary", to prepare a least-cost National Energy Plan;

(2) to establish an Office of Climate Protection in the Department of Energy;

(3) to provide for the establishment and financing of energy efficiency research and development projects;

(4) to establish criteria to be used by the Secretary to determine priorities in energy research and development and, to consider global climate change in all research and development policies;

(5) to require States to update their energy conservation plans and establish new targets for conservation;

(6) to commercially develop solar, fuel cell, hydrogen, and other renewable energy technologies;

(7) to provide for the establishment and financing of an advanced passively safe nuclear reactor research program;

(8) to provide for the preparation of a comprehensive report on research, development, and demonstration technology for the production of electricity from thermonuclear fusion;

(9) to provide for the preparation of a comprehensive report on the clean coal program's implications for global climate change;

(10) to provide financial assistance for demonstration projects for natural gas-powered vehicles;

(11) to study the natural resources that would be affected by global climate change;

(12) to expand financial support for ongoing and new research initiatives at NOAA, NASA, NSF, USGS, and NIST;

(13) to require an interagency study of the contribution international deforestation and reforestation play in global climate change;

(14) to call for the convening of international conferences on nuclear power, a strengthening of the Montreal Protocol, and a special office at UNEP and WMO to monitor global carbon dioxide production; and

(15) to address world population growth by establishing a policy and providing financial assistance for international family planning and information services.

SEC. 3. NATIONAL GOAL.—The Congress hereby establishes as national goals—

(a) that the introduction into the atmosphere of CO_2 from the United States of America shall be reduced from 1988 levels by at least 20 percent by the year 2000 through a mix of Federal and State energy policies that are designed to mitigate the costs and risks, both economic and environmental, associated with meeting national energy needs while reducing the generation of carbon dioxide and trace gases and sustaining economic growth and development; and

(b) the establishment of an international global agreement on the atmosphere by 1992.

TITLE I—NATIONAL ENERGY PLAN

(a) Not later than 18 months after the enactment of this Act, the Secretary, and the Administrator of the Environmental Protection Agency, in consultation with the Secretary of the Interior, the National Academy of Sciences and other agencies, shall prepare and after public review and comment, transmit to Congress a "least-cost national energy plan" for meeting the national goal set out in section 3 of this Act. For purposes of the plan, (1) "energy resources" shall be defined as those sources of additional energy supply involving either the production of additional energy or additional improvements in the efficiency of energy processing and end use.

(2) "Cost-effective" shall be defined as those resources projected to be reliable and available within a needed time frame, and that could be used to meet anticipated energy needs at an estimated incremental system cost no greater than that of the least-cost similarly reliable and available alternative measure of resource, or any combination thereof.

(3) "System costs" shall be defined as all direct costs of a resource over its effective life, including, if applicable, the cost of distribution and transmission to the consumer and, also including among other factors, waste disposal costs and

fuel costs (including projected increase), and such quantifiable environmental and national security costs and benefits as the Secretary and the Administrator determine are directly attributable to such resources.

(4) "Estimated incremental system cost" of any conservation resource shall not be treated as greater than that of any other resource unless the incremental system cost of such conservation resources is in excess of at least 110 percent of the incremental system cost of the other resource.

(b) The plan shall include—

(1) an assignment of the priorities among energy resources that the Secretary determines to be cost-effective, according to their impact on the global climate;

(2) a range of national energy demand forecasts for the short-, medium-, and long-term (at least 50 years), reflecting plausible high and low economic growth scenarios, and assuming no improvements in current average efficiencies of energy use in new buildings, machines, and vehicles;

(3) a comprehensive inventory of resources availability and system cost, taking into account all sectors of energy use and production which shall include but not be limited to—

(i) coal, including clean coal technologies and underground coal gasification;

(ii) energy efficiency, including existing technologies for increased efficiency and end use, as well as the potential of further research and development;

(iii) efficiency improvements and technological gains in electrical energy generation and transmission and energy extraction;

(iv) other alternative energy sources such as renewable resources, solar, nuclear fission, nuclear fusion geothermal, fuel cells, and hydroelectric power; and

(v) improvements in the fuel efficiency of automobiles and light trucks.

(4) targets for the cost-effective resource acquisitions that will be needed to ensure that the Nation can meet short-, medium-, and long-term energy needs without exceeding the national goal for carbon dioxide generation;

(5) a 2-year action plan for meeting the plan's resource acquisition targets, including, but not limited to, all practicable actions within the Secretary's and other Federal agencies' current legislative authority;

(6) a research and development plan for investigating promising but unproven technologies identified in the planning process as potentially significant future contributors to meeting the plan's goals;

(7) recommendations for any new Federal legislation that may be needed to meet the plan's goals, including estimates of accompanying carbon dioxide and trace gases generation; and

(8) recommendations for any new State agency or legislative actions that are needed to meet the plan's goals, and for any new Federal policies that are needed to encourage such actions, including estimates of accompanying carbon dioxide and costs impacts of such actions.

(c) Immediately following submission to Congress of the least-cost national energy plan, the Department of Energy shall implement the provisions of its action plan to the maximum extent practicable.

(d) The plan, its action plan, and its research and development plan shall be revised and resubmitted to the Congress every 2 years.

TITLE II—OFFICE OF CLIMATE PROTECTION

SEC. 201. In order to elevate the priority attached to climate change considerations within the Department of Energy, there is hereby established the Office of Climate

Protection. The Director of the Office shall be appointed by the President, by and with the consent of the Senate, and shall report directly to the Deputy Secretary. This Office shall be responsible for—

(a) the Department of Energy's participation in studies, environmental assessments and other work being conducted by the various domestic and international agencies involved in global climate change analysis; and

(b) monitoring United States' energy policies for atmospheric and global warming effects and providing an annual report on these effects to Congress.

TITLE III—ENERGY EFFICIENCY

Subtitle A

SEC. 301. The Secretary in conjunction with appropriate Federal agencies shall—

(a) give a high priority to improvements in energy efficiency in departmental planning, research and development programs, private assistance programs, and to improvements in buildings and equipment of the Department;

(b) submit to Congress within 1 year after the enactment of this title, and every 3 years thereafter, a report evaluating the policy options that would be necessary to produce a decrease of 2 through 4 percent

per year in the energy use per unit of gross national product in the United States through the year 2005. These policy options and programs shall be ranked according to their cost effectiveness.

SEC. 302. (a) The President's budget request for fiscal years 1991 through 1993 shall include the Secretary's recommendations of amounts to be set aside for new initiatives in energy efficiency research, development, and demonstration. Funds made available for new initiatives shall supplement and not supplant funds available to complete on-going energy efficiency research and development projects supported in whole or in part by the Secretary during the fiscal year 1990. Funds made available for new initiative shall be used by the Secretary to support the most promising and deserving new ideas in energy efficiency research and development brought to the attention of the Secretary during the previous fiscal year.

(b)(1) There is hereby authorized to be appropriated to the Secretary for the energy efficiency research, development, and demonstration programs of the Secretary, an amount not to exceed $209,181,000 in fiscal year 1991, of which $6,000,000 shall be available for new initiatives, as set forth below—

(A) for transportation energy efficiency research, development, and demonstration there is authorized to

be appropriated to the Secretary an amount not to exceed $65,460,000 of which $2,000,000 shall be made available for new initiatives;

(B) for industrial energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $46,740,000, of which $1,000,000 shall be available for new initiatives;

(C) for buildings and community systems energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $58,100,000 of which $2,000,000 shall be available for new initiatives;

(D) for multisector energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $37,050,000, of which $1,000,000 shall be available for new initiatives; and

(E) for energy efficiency research, development, and demonstration policy and management, there is authorized to be appropriated to the Secretary an amount not to exceed $1,797,000.

(2) There is hereby authorized to be appropriated to the Secretary for the energy efficiency research, development, and demonstration programs of the Secretary, an amount not

to exceed $253,000,000 in fiscal year 1992, of which $7,000,000 shall be available for new initiatives as set forth below—

(A) for transportation energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $84,000,000, of which $3,000,000 shall be made available for new initiatives;

(B) for industrial energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $45,000,000 of which $1,000,000 shall be available for new initiatives;

(C) for buildings and community systems energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $55,000,000 of which $2,000,000 shall be available for new initiatives;

(D) for multisector energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $64,000,000, of which $1,000,000 shall be available for new initiatives; and

(E) for energy efficiency research, development, and demonstration policy and management, there is au-

thorized to be appropriated to the Secretary an amount not to exceed $5,000,000.

(3) There is hereby authorized to be appropriated to the Secretary for the energy efficiency research, development, and demonstration programs of the Secretary, an amount not to exceed $301,000,000 in fiscal year 1993, of which $8,000,000 shall be available for new initiatives, as set forth below—

(A) for transportation energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $98,000,000 of which $3,000,000 shall be made available for new initiatives;

(B) for industrial energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $50,000,000 of which $2,000,000 shall be available for new initiatives;

(C) for buildings and community systems energy efficiency research, development, and demonstration there is authorized to be appropriated to the Secretary an amount not to exceed $65,000,000 of which $2,000,000 shall be available for new initiatives;

(D) for multisector energy efficiency research, development, and demonstration there is authorized to be

appropriated to the Secretary an amount not to exceed $83,000,000, of which $1,000,000 shall be available for new initiatives; and

(E) for energy efficiency research, development, and demonstration policy and management, there is authorized to be appropriated to the Secretary an amount not to exceed $5,000,000.

SEC. 303. (a) As used in this section and in section 304 the term "joint research and development venture" has the meaning given such term in the National Cooperative Research Act of 1984 (98 Stat. 1815).

(b)(1) The Secretary shall solicit proposals in accordance with the provisions of this section for joint research and development ventures for the commercial demonstration of energy efficiency technologies that show significant promise for cost-effective commercial application and that can contribute significantly to reducing the rate and scope of carbon dioxide and trace gas generation. Each joint research and development venture under this section shall include manufacturing firms, investors, and such other participation as the Secretary deems appropriate to achieve the purposes of this section.

(2) Not later than 120 days after the date of the enactment of this section the Secretary shall publish plans to im-

plement this section, provide opportunity for public comment on such plans, and report to Congress on the plans.

(3)(A) Not later than 1 year after the date of the enactment of this subsection the Secretary shall issue a general request for proposals under this subsection. Such general request shall contain a description of the criteria the Secretary will use in awarding financial assistance under this subsection. The primary such criterion shall be the probability of significant near-term impact of the proposal on the rate of carbon dioxide and trace gas generation. The secondary criterion shall be the probability of significant near-term impact of the proposal on reduction of oil imports. The Secretary may include such other criteria as the Secretary finds appropriate, including the net cost under the proposal in Federal financial assistance and the likelihood of early commercial application of technology demonstrated under the proposal.

(B) Proposals shall be submitted to the Secretary within 120 days after such general solicitation is published in the Federal Register.

(C) The Secretary shall not provide Federal financial assistance for more than 50 percent of the costs of any proposal under this subsection as estimated by the Secretary at the time of acceptance of such proposal. For purposes of this subsection, other Federal funds, existing facilities, equipment

and supplies, and previously expended research and development funds are not cost sharing.

(4) The Secretary shall issue general requests for proposals under this subsection on the first and second anniversaries of the issuance under paragraph (3).

(5)(A) The Secretary may provide technical assistance to persons developing proposals under this subsection.

(B) The Secretary may provide technical and financial assistance in accordance with this subsection to proposals that have been accepted by the Secretary under this subsection.

(C) There is authorized to be appropriated to the Secretary for purposes of this subsection not more than $50,000,000 for each of the fiscal years 1991, 1992, and 1993, such amounts to remain available until expended.

SEC. 304. (a) The Secretary shall establish and provide financial assistance to joint research and development ventures with such specialized private firms and investors as the Secretary deems appropriate in order to establish at least 5 regional centers for energy-intensive industries. The centers shall conduct basic and applied research and development on common industrial processes. The centers shall focus their efforts on changes to industrial processes that may result in improved energy efficiency. The centers may also conduct research on other improvements of benefit to industry so long

as energy efficiency improvements are an integral part of that research. In locating the regional centers under this section, the Secretary shall consider the regional distribution of energy-intensive industries. The research centers shall be established in the region in which the Secretary determines each energy-intensive industry is located.

(b) The regional centers under this paragraph shall carry out research and development efforts to reduce the production of CO_2 and trace gases into the atmosphere by improving the quality and energy efficiency of industrial processes.

(c) The research and development strategy under this paragraph shall be guided by—

(1) a detailed characterization of the needs of domestic manufacturing industries;

(2) a close working relationship with all sectors of the domestic manufacturing industry; and

(3) coordination among the centers to pool and conserve resources.

(d) There is authorized to be appropriated to the Secretary $5,000,000 for fiscal year 1991, $15,000,000 for fiscal year 1992, and $25,000,000 for fiscal year 1993. Industries for which the centers are established shall contribute matching funds starting in 1992.

SEC. 305. (a) As used in this section, the term "Federal building" has the meaning given such term in section 521 of

the National Energy Conservation Policy Act and includes facilities used in connection with such Federal building.

(b)(1) The Secretary shall establish a Federal energy analysis team to analyze, and make recommendations with respect to energy efficiency and the use of renewable energy in, specific Federal buildings selected by the Secretary under this section. The team shall be made up of individuals—

(A) engaged in research on energy efficiency or the use of renewable energy in buildings at the National Laboratories of the Department of Energy; and

(B) nominated by the Secretary of Defense, the Administrator of the General Services Administration and the Director of the National Institute of Standards and Technology, respectively, on the basis of their expertise in energy efficiency and the use of renewable forms of energy in buildings. Persons who serve on the team shall be transferred to the team for purposes of this section without loss of salary or benefits.

(2) The team shall conduct an analysis of energy use in Federal buildings designated by the Secretary under paragraph (3) to determine the potential for the use of renewable forms of energy and for improved energy efficiency in such buildings and make recommendations for cost-effective renewable energy and energy efficiency improvements in such buildings. For purposes of this section an improvement shall

be considered cost effective if the cost of the energy saved or displaced by the improvement exceeds the cost of the improvement over the life or remaining term of lease of the building.

(3) The Secretary shall designate buildings to be analyzed by the team so as to obtain a sample of buildings of the types and in the climates that is representative of the Federal buildings owned or leased by Federal agencies in the United States that consume the major fraction of the energy consumed in Federal buildings.

(4) The Secretary shall submit a plan for implementing this subsection to Congress within 6 months after the date of the enactment of this section.

(5) The team shall report its findings and recommendations based on the analyses carried out under paragraph (2) to the Secretary and to the head of the agency owning or leasting each building analyzed within 18 months after the date of the enactment of this section.

(b)(1) The Secretary shall use the results of the analyses under subsection (a) to develop goals for 1995 for energy efficiency and the use of renewable energy in Federal buildings generally and in the categories identified by the Secretary under subsection (a)(3). Goals developed under this subsection shall be submitted to Congress within 24 months after the date of the enactment of this section.

(2) Any agency that chooses not to implement promptly the recommendations of the team with respect to a Federal building analyzed under subsection (a)(2) shall provide Congress with a written explanation of the reasons for such choice.

(3) Any agency that implements the recommendations of the team with respect to a Federal building analyzed under subsection (a)(2) may retain for purposes of furthering the objectives of the agency one-half of the dollar savings realized as a result of such recommendations. The Secretary shall consult with the heads of the appropriate Federal agencies to insure that the maximum dollar savings under this section are realized.

(c) There is hereby authorized to be appropriated to the Secretary for purposes of carrying out this section $2,500,000.

SEC. 306. REPEAL OF PROHIBITIONS ON SUPPLY AND INSTALLATION OF RESIDENTIAL ENERGY CONSERVATION MEASURES BY UTILITIES.—Section 216 of the National Energy Conservation Policy Act (42 U.S.C. 8217) is repealed and subsequent sections are renumbered accordingly.

SEC. 307. HOME ENERGY EFFICIENCY RATINGS.—Title II of the National Energy Conservation Policy Act is amended by adding a new part 6 as follows:

"PART 6—RESIDENTIAL ENERGY EFFICIENCY RATINGS

"SEC. 271. (a) Within 12 months after the date of the enactment of this section the Secretary in consultation with the Secretary of Housing and Urban Development and State governments shall by rule promulgate guidelines for regulations to be formulated and implemented by State governments that would require the assignment of an energy efficiency rating to residential buildings.

"(b) The rule under subsection (a) shall—

"(1) provide for a numerical rating of the efficiency with which any residential building may be supplied with heating and cooling energy on an annual basis, and evaluate the practicality of including major energy consuming appliances in such rating;

"(2) provide that all residential buildings receive a rating at time of sale;

"(3) ensure that the rating is prominently communicated to potential buyers and renters; and

"(4) ensure that the rating system is designed to facilitate its use by the secondary mortgate markets to promote energy efficiency.

"(c) Within 12 months of the date of enactment of this Act, the Secretary shall establish a program to provide technical and managerial support for State and local governments adopting energy efficiency rating systems or building codes.

The program shall utilize the Federal Government's experience in developing Federal building energy performance standards and shall provide compliance methods, educational materials for builders and code officials, and other technical support.

"(d) For purposes of the rule under subsection (a) supply of energy to any residential building from the level of the contribution of renewable sources shall not result in a reduction in the energy efficiency rating of such building.".

SEC. 308. ENERGY EFFICIENCY LABELS FOR MAJOR APPLICATIONS OF INCANDESCENT AND FLUORESCENT LAMPS.—Part B of title III of the Energy Policy and Conservation Act, as amended, is further amended—

(a) in section 322(a) by striking paragraph (14) and inserting in lieu thereof new paragraphs (14), (15) and (16) as follows:

"(14) Incandescent lamps which are the predominant consumers of energy used for lighting in the commercial, industrial, and residential sectors.

"(15) Fluorescent lamps which are the predominant consumers of energy used for lighting in the commercial, industrial, and residential sectors.

"(16) Any other type of consumer product that the Secretary classifies as a covered product under subsection (b).".

(b)(1) in section 324(a)(1) by inserting after the phrase "through (12)", "(14) and (15)"; and

(2) in the remaining provisions of section 324 by striking the phrase "paragraph (14)" everywhere it appears and inserting in lieu thereof the phrase "paragraph (16)";

(c)(1) in section 325(i) by striking the phrase "paragraph (14)" everywhere it appears and inserting in lieu thereof the phrase "paragraph (16)"; and

(2) by adding at the end of subsection 325(i) a new paragraph (4) as follows:

"(4) The Secretary, before January 1, 1990, shall prescribe an energy conservation standard for each of the covered products specified in paragraphs (13) and (14) of section 322(a). Concurrent with the Secretary's prescription of such standards the Secretary shall also prescribe test procedures.".

SEC. 309. ENERGY EFFICIENCY LABELS FOR WINDOWS.—Within 18 months of the date of enactment of this Act, the Secretary, after consultation with the National Institute of Standards and Technology, shall establish labels for thermal and optical properties and performance for windows and window systems.

SEC. 310. REVIEW.—The Secretary shall periodically review standards and labels established under sections 308

and 309 at least every 3 years and strengthen the standards for the products or any other energy-consuming device that the Secretary deems justified.

Subtitle B

AMENDMENTS TO PUBLIC UTILITY REGULATORY POLICIES ACT OF 1978

SEC. 311. ENCOURAGEMENT OF LEAST COST INVESTMENT.—The Public Utility Regulatory Policies Act of 1978, Public Law 95–617 (November 9, 1978), as amended, is further amended by inserting the following new section after section 113 and renumbering the sections accordingly:

"SEC 114. LEAST COST INVESTMENT.

"(a) ADOPTION OF STANDARDS.—Not later than 2 years after the date of enactment of this section, each State regulatory authority (with respect to each gas utility and electric utility for which it has ratemaking authority) shall provide public notice and conduct a hearing respecting the standard established by subsection (b) and, on the basis of such hearing, shall adopt and implement the standard established by subsection (b) if, and to the extent, such authority determines that such adoption and implementation is appropriate and consistent with otherwise applicable State law. For purposes of any determination made on the basis of such hearing and any review of such determination in any court in

accordance with section 125, the purposes of this title supplement otherwise applicable State law.

"(b) ESTABLISHMENT.—The following Federal standard is hereby established:

"The rates permitted to be charged by a gas utility or electric utility shall be such that the implementation of least cost supply measures permits the utility to realize higher earnings than would be realized from the implementation of other supply measures. For purposes of this standard, the term 'implementation of least cost supply measures' shall mean actions (including, but not limited to, conservation and other means of demand reduction) taken to provide adequate and reliable service to consumers with the incurrence of lowest total costs to society, such costs to include costs incurred by the utility and its customers, and environmental costs.

"(c) PROCEDURAL REQUIREMENTS.—Each State regulatory authority (with respect to each gas utility and electric utility for which it has ratemaking authority) within the 2-year period specified in subsection (a), shall (1) adopt and implement, pursuant to subsection (a), the standard established by subsection (b) or, (2) if the standard is not adopted and implemented, such authority shall state in writing that it has determined not to adopt and implement such standard,

together with the reasons for such determination. Such statement of reasons shall be available to the public.

"(d) DEFINITIONS.—(1) For purposes of this section, the term 'gas utility' means any person who is engaged in the local distribution and sale of natural gas to any ultimate consumer and over whom a State regulatory authority has ratemaking authority.

"(2) for purposes of this section, the term 'electric utility' means any person who is engaged in the local distribution and sale of electricity to any ultimate consumer and over whom a State regulatory authority has ratemaking authority.

"SEC. 115. LEAST COST INVESTMENT FOR NONREGULATED UTILITIES.

"(a) ADOPTION OF STANDARDS.—Not later than two years after the date of enactment of this section, each nonregulated electric utility and nonregulated gas utility shall provide public notice and conduct a hearing respecting the standard established by subsection (b) and, on the basis of such hearing, shall adopt and implement the standard established by subsection (b) if, and to the extent, such utility determines that such adoption and implementation is appropriate and consistent with otherwise applicable State law. For purposes of any determination made on the basis of such hearing and any review of such determination in any court in

accordance with section 125, the purposes of this title supplement otherwise applicable State law.

"(b) ESTABLISHMENT.—The following Federal standard is hereby established:

"Each nonregulated gas utility and nonregulated electric utility shall implement least cost supply measures. For purposes of this standard, the phrase 'implement least cost supply measures' shall mean actions (including, but not limited to, conservation and other means of demand reduction) taken to provide adequate and reliable service to consumers with the incurrence of lowest total costs to society, such costs to include costs incurred by the utility and its customers, and environmental costs.

"(c) PROCEDURAL REQUIREMENTS.—Each nonregulated electric utility and nonregulated gas utility shall, within the 2-year period specified in subsection (a), (1) adopt and implement, pursuant to subsection (a), the standard established by subsection (b) or, (2) if the standard is not adopted and implemented, such utility shall state in writing that it has determined not to adopt and implement such standard, together with the reasons for such determination. Such statement of reasons shall be available to the public.

"(d) DEFINITIONS.—(1) For purposes of this section, the term 'nonregulated gas utility' means any person who is

engaged in the local distribution and sale of natural gas to any ultimate consumer and over whom a State regulatory authority does not have ratemaking authority.

"(2) For purposes of this section the term 'nonregulated electric utility' means any person who is engaged in the local distribution and sale of electricity to any ultimate consumer and over whom a State regulatory authority does not have ratemaking authority.".

SEC. 312. DEFINITIONS.—Section 3 of the Federal Power Act, as amended (16 U.S.C. 796 et seq.), is further amended by inserting the following definitions after the definition of "qualifying cogenerator" and renumbering the definitions accordingly:

"(19)(A) 'qualifying conservation' means any reduction at any time in the demand for electric energy by the customers of a utility, which reduction—

"(i) would not occur but for payments received by a qualifying conservation entity; and

"(ii) the Commission determines, by rule, meets such requirements as the Commission may, by rule, prescribe;

"(B) 'qualifying conservation entity' means a person who—

"(i) the Commission determines, by rule meets such requirements as the Commission may, by rule, prescribe;

"(ii) is not primarily engaged in the generation or sale of electric power (other than electric power from cogeneration facilities or small power production facilities);".

SEC. 313. PURCHASES OF QUALIFYING CONSERVATION BY UTILITIES.—Section 210 of the Public Utility Regulatory Policies Act of 1978 (16 U.S.C. 824a–3), as amended, is further amended by—

(a) inserting the following new subsection after subsection (a) and relettering the remaining subsections accordingly:

"(b) CONSERVATION RULES.—Not later than one year after the date of enactment of this subsection, the Commission shall prescribe, and from time to time thereafter revise, such rules as it determines necessary to encourage the achievement of qualifying conservation. Such rules shall require electric utilities to offer to purchase qualifying conservation from qualifying conservation entities under such terms as the Commission may prescribe and shall include provisions concerning verification of the achievement of qualifying conservation. Such rules shall be prescribed, after consultation with representatives of Federal and State regulatory agencies

having ratemaking authority for electric utilities, and after public notice and a reasonable opportunity for interested persons (including State and Federal agencies) to submit oral as well as written data, views, and arguments.";

(b) striking subsection (b) and inserting the following in lieu thereof:

"(c) RATES FOR PURCHASES BY ELECTRIC UTILITIES.—The rules prescribed under subsections (a) and (b) shall insure that, in requiring any electric utility to offer to purchase electric energy from any qualifying cogeneration facility or qualifying small power production facility, or to purchase qualifying conservation from a qualifying conservation entity, the rates for such purchase—

"(1) shall, in the case of purchases from qualifying cogeneration facilities and qualifying small power production facilities, be just and reasonable to the electric consumers of the electric utility;

"(2) shall be in the public interest;

"(3) shall not discriminate against qualifying cogenerators, qualifying small power producers, or qualifying conservation entities. No such rule prescribed under subsection (a) shall provide for a rate which exceeds the incremental cost to the electric utility of alternative electric energy. Rules prescribed under subsection (b) shall give State regulatory authorities and

nonregulated electric utilities the option of restricting the rate paid for qualifying conservation to an amount no greater than—

"(A) the incremental cost of alternative electric energy; or

"(B) the amount by which the incremental cost of alternative electric energy exceeds the price for the generation of electric energy paid by the customers whose demand for electric energy is reduced as a result of qualifying conservation.";

and

(c) adding the following at the end of subsection (d):

"The term 'incremental cost of alternative electric energy' means, with respect to purchases of qualifying conservation from qualifying conservation entities, the cost to the purchasing electric utility of the electric energy which, but for the purchase from such conservation entity, such utility would generate or purchase from another source.".

SEC. 314. CONFORMING CHANGES.—Section 210 of the Public Utility Regulatory Policies Act of 1978 (16 U.S.C. 824a–3), as amended, is further amended—

(a) in subsection (f) by striking "subsection (a) of this section or revised under such subsection" in each place it appears and substituting "subsections (a) or (b)

of this section or revised under such subsections" in lieu thereof;

(b) in subsection (g) by striking "subsection (a)" and substituting "subsections (a) or (b)" in lieu thereof;

(c) in subsection (g) by striking "or qualifying cogenerator" and inserting "qualifying cogenerator, or qualifying conservation entity" in lieu thereof;

(d) in paragraph (2) of subsection (h) by striking "or qualifying small power producer" and substituting "qualifying small power producer, or qualifying conservation entity" in lieu thereof;

(e) in subsection (j) by striking "and 'qualifying cogenerator' " and substituting " 'qualifying cogenerator', 'qualifying conservation', and 'qualifying conservation entity' " in lieu thereof; and

(f) in subsection (j) by striking "3(17) and 3(18)" and substituting "3(17), 3(18) and 3(19)" in lieu thereof.

TITLE IV—ENERGY RESEARCH AND DEVELOPMENT PRIORITIES

SEC. 401.—The Secretary of Energy shall establish priorities, using the following criteria in order of importance, for research and development programs:

(1) potential to reduce generation of carbon dioxide and trace gases sooner than alternative projects;

(2) the projected cost effectiveness of the energy ultimately to be produced or saved, including an evaluation of the likelihood of success of the research;

(3) the environmental and public health impacts of the energy ultimately to be produced or saved by the specific research;

(4) the national security impact of the energy produced or saved, including its projected reduction of oil imports and contribution to the diversity of the fuel mix;

(5) the obstacles inherent in private industry's development of new energy technologies and steps necessary for establishing or restoring technical leadership in the area of renewable energy technologies, including, but not limited to, solar, fuel cells, and hydrogen;

(6) the impact of given research in the area of fundamental scientific inquiry; and

(7) the impact of the research on special or targeted populations, including low-income or aged persons.

TITLE V—STATE ENERGY CONSERVATION PROGRAM

STATE ENERGY CONSERVATION GOALS

SEC. 501. Section 364 of the Energy Policy and Conservation Act (42 U.S.C. 6324) is amended to read as follows:

"ENERGY CONSERVATION GOALS

SEC. 364. Each State energy conservation plan with respect to which assistance is made available under this part on or after October 1, 1990, shall contain a goal consisting of a reduction, as a result of the implementation of such plan, of 10 percent or more in the amount of energy consumed in such State in the year 2000 from the projected energy consumption, as of October 1, 1990, for such State in the year 2000.".

REQUIRED STATE ENERGY CONSERVATION PLAN ELEMENTS AND CONSOLIDATION OF ENERGY EXTENSION SERVICE

SEC. 502. (a) IN GENERAL.—Section 362(c) of the Energy Policy and Conservation Act (42 U.S.C. 6322(c)) is amended—

(1) by striking "and" at the end of paragraph (4);

(2) by striking the period at the end of paragraph (5) and inserting in lieu thereof a semicolon; and

(3) by adding at the end thereof the following new paragraphs:

"(6) and energy emergency planning program for an energy supply disruption which shall include a specific implementation strategy regional coordination and may include planning for petroleum, electricity, natural gas, coal, and nuclear power supply and delivery disruptions;

"(7) procedures for ensuring that effective coordination exists among various local, State, and Federal energy conservation programs within the State, including any program administered within the Office of State and Local Assistance Programs of the Department of Energy as of December 31, 1987, and the Low Income Energy Assistance Program administered by the Department of Health and Human Services; and

"(8) programs to implement all the functions of the Energy Extension Service, as provided by law on the day before the date of enactment of the State Energy Conservation Programs Improvement Act of 1989, which shall—

"(A) include programs for identification, development, and demonstration of energy efficiency opportunities, techniques, methods, materials, and equipment (including those that are responsive to local needs or resources) and alternative energy

technologies such as solar heating and cooling for agricultural, commercial, and small business operations, individual energy consumers, and new existing residential, commercial, and agricultural buildings or structures;

"(B) provide for technical assistance, instructions, information dissemination, and practical demonstrations with respect to energy efficiency opportunities;

"(C) provide, to the maximum extent practicable within personnel and funding limitations, active outreach energy extension assistance (including information on end-user technoloy requirements) at the local level through appropriate offices (Including metropolitan offices) and through county agents and technical staff assistants;

"(D) make maximum use of existing outreach or delivery mechanisms or programs and include, to the maximum extent practicable, any State, local, university, college, or other organization's programs for energy information, education, or technology transfer which have activities or purposes similar to those of this part; and

"(E) establish and implement policies and procedures designed to assure that assistance pro-

vided under this part does not replace or supplant the expenditure of other Federal or State or local funds for the same purposes, but instead supplements such funds and increases the expenditure of such State or local funds to the maximum extent practicable.".

(b) ELIMINATION OF EES.—The National Energy Extension Services Act (title V of Public Law 95–39) is repealed.

OPTIONAL STATE ENERGY CONSERVATION PLAN ELEMENTS AND CONSOLIDATION OF SUPPLEMENTAL STATE ENERGY CONSERVATION PLAN

SEC. 503. IN GENERAL.—Section 362(d) of the Energy Policy and Conservation Act (42 U.S.C. 6322(d)) is amended—

(1) by striking "and" at the end of paragraph (4);

(2) by striking the period at the end of paragraph (5) and inserting in lieu thereof a semicolon; and

(3) by adding at the end thereof the following new paragraphs:

"(6) programs for financing energy efficiency and renewable energy capital investments, projects, and programs—

"(A) which may include loan programs and performance contracting programs for leveraging of additional public and private sector funds, and

programs which allow rebates, grants, or other incentives for the purchase and installation of energy efficiency and renewable energy measures; or

"(B) in addition to or in lieu of programs described in subparagraph (A), which may be used in connection with public or nonprofit buildings owned and operated by a State, a political subdivision of a State or an agency or instrumentality of a State, or an organization exempt from taxation under section 501(c)(3) of the Internal Revenue Code of 1986;

"(7) programs to increase transportation energy efficiency, including programs to accelerate the use of alternative transportation fuels for State government vehicles, fleet vehicles, taxis, mass transit, and privately owned vehicles;

"(8) programs for encouraging and for carrying out energy audits with respect to buildings and industrial plants within the State;

"(9) programs to promote the adoption of integrated energy plans which provide for—

"(A) periodic evaluation of a State's energy needs, available energy resources (including greater energy efficiency), and energy costs; and

"(B) utilization for reliable energy supplies, including greater energy efficiency, that meet applicable safety, environmental, and policy requirements at the lowest cost;

"(10) programs to promote energy efficiency in residential housing, such as—

"(A) programs for development and promotion of energy efficiency rating systems for newly constructed housing and existing housing so that consumers can compare the energy efficiency of different housing; and

"(B) programs for the adoption of incentives for builders, utilities, and mortgage lenders to build, service, or finance energy efficient housing; and

"(11) programs to protect consumers from any unfair or deceptive acts or practices which relate to the implementation of energy efficiency measures and renewable resources energy measures.".

(b) ELIMINATION OF SSECP.—Section 367 of the energy policy and conservation act (42 U.S.C. 6327) is repealed.

AUTHORIZATION OF APPROPRIATIONS

SEC. 504. (a) STATE PLAN PROGRAM.—Section 365(F) of the Energy Policy and Conservation Act (42 U.S.C. 6325(F) is amended to read as follows:

"(f) For the purpose of carrying out this part, there are authorized to be appropriated $25,000,000 for fiscal year 1991, $35,000,000 for fiscal year 1992, and $45,000,000 for fiscal year 1993.".

(b) ENERGY CONSERVATION PROGRAM FOR SCHOOLS AND HOSPITALS.—Section 397 of the Energy Policy and Conservation Act (42 U.S.C. 6371f(a)) is amended to read as follows:

"AUTHORIZATION OF APPROPRIATIONS

SEC. 397. For the purpose of carrying out this part, there are authorized to be appropriated $40,000,000 for fiscal year 1991, $50,000,000 for fiscal year 1992, and $60,000,000 for fiscal year 1993.".

(c) WEATHERIZATION ASSISTANCE.—Section 422 of the Energy Conservation Production Act (42 U.S.C. 6872) is amended to read as follows):

"AUTHORIZATION OF APPROPRIATIONS

"SEC. 422. There are authorized to be appropriated for purposes of carrying out the weatherization program under this part $200,000,000 for fiscal year 1991 and such sums as may be necessary for 1992 and 1993.".

SEC. 505. STATE ENERGY ADVISORY BOARD.—Section 365 of the Energy Policy and Conservation Act (42 U.S.C. 6325) is amended by adding at the end the following:

"(g)(1) There is hereby established within the Department of Energy a State Energy Advisory Board (hereafter in

this subsection referred to as the 'Board') which shall consist of not less than 10 nor more than 15 members appointed by the Secretary. Not less than one-half of the members of the Board shall be persons who serve as directors for the State agency, or a division of such agency, responsible for developing State energy conservation plans pursuant to section 362. At least 1 member of the Board shall be a director of a State weatherization assistance program. Other members shall be appointed from other persons, including those who have experience in energy efficiency or renewable energy programs for the private sector, consumer interest groups, utilities, public utility commissions, educational institutions, or research institutions.

"(2) The Board shall—

"(A) make recommendations with respect to the energy efficiency objectives of the programs carried out under this part, part G of this title, and under part A of title IV of the Energy Conservation and Production Act to the Assistant Secretary for Conservation and Renewable Energy, the Director of the Office of State and Local Assistance Programs, and the Director of the Building and Community Systems Office within the Department of Energy;

"(B) serve as a liaison between the States and such Department on energy efficiency and renewable energy resource programs;

"(C) recommend changes to State and Federal energy policies; and

"(D) encourage technology transfer of the results of research and development activities carried out by the Federal Government with respect to energy efficiency and renewable energy resources.

"(3) The Secretary shall designate 1 of the members of the Board to serve as its chairman and 1 to serve as its vice chairman. The chairman and vice chairman shall serve in those offices no longer than 2 years.

"(4) The Secretary shall provide the Board with such services and facilities as may be necessary for the performance of its functions.

"(5) The Board shall be nonpartisan.

"(6) The Board may adopt administrative rules and procedures and may elect one of its members Secretary of the Board.

"(7) The Secretary shall reimburse members of the Board for expenses (including travel expenses) necessarily incurred by them in the performance of their duties.

"(8) The Board shall meet at least annually and shall submit an annual report to the Secretary and the Congress

on the activities carried out by the Board in the previous fiscal year, including any recommendations it may have for administrative or legislative changes.".

UPDATE OF ENERGY CONSERVATION PROGRAM FOR SCHOOLS AND HOSPITALS

SEC. 506. (a) NON-FEDERAL SHARE OF A PROJECT.—Section 396(b)(1) of the Energy Policy and Conservation Act (42 U.S.C. 6371e(b)(1)) is amended by adding at the end thereof the following: "The non-Federal share of the costs of any such energy conservation project may be provided by using programs of innovative financing for energy conservation projects, including loan programs and performance contracting.".

(b) DEFINITION.—Section 391(1) of such Act (42 U.S.C. 6371(1)) is amended by striking "April 20, 1977" and inserting in lieu thereof "December 31, 1984".

WEATHERIZATION ASSISTANCE FOR LOW-INCOME PERSONS

SEC. 507. (a) WAIVER OF 40-PERCENT REQUIREMENT.—Section 415(a) of the Energy Conservation and Production Act (42 U.S.C. 6865(a)) is amended—

(1) in the first sentence, by striking "An average" and inserting in lieu thereof "(1) Except as provided in paragraph (2), and average"; and

(2) by adding at the end the following:

"(2)(A) The Secretary may approve a State application to waive the 40-percent requirement established in paragraph (1) if the State includes in the State's plan—

"(i) an energy evaluation which establishes priorities for selection of weatherization measures bases on their contribution to energy efficiency; and

"(ii) a standard for determining whether to invest in individual measures based on a rate of return that will ensure that investment in each measure is an appropriate use of funds.

"(B) For States applying for a waiver under this paragraph, the Secretary shall establish standards for determining whether the energy audit techniques of each such State measure—

"(i) the energy requirement of individual dwellings;

"(ii) the rate of return of each conservation investment; and

"(iii) the interaction between conservation measures. State applications for waivers shall be judged on these standards.

"(c) The Secretary shall make information on energy evaluation instruments available to States applying for a

waiver under this paragraph and shall provide training for State and local agencies in the implementation for such instruments.".

(b) DWELLING UNIT LIMITATION.—Section 415(c) of such Act (42 U.S.C. 6865(c)) is amended—

(1) in paragraph (1), by striking "The expenditure" and inserting in lieu thereof "except as provided in paragraphs (3) and (4), the expenditure"; and

(2) by adding at the end thereof the following new paragraphs:

"(3) Beginning with fiscal year 1991, the $1,600 per dwelling unit limitation provided in paragraph (1) shall be adjusted annually by increasing the limitation amount by an amount equal to the percentage increase in the Consumer Price Index for the previous fiscal year multiplied by the limitation amount for such previous fiscal year. The increase under the preceding sentence for any fiscal year shall not exceed 3 percent.

"(4)(A) In addition to the average per dwelling unit limitation applicable in a State under paragraphs (1) and (3), the Secretary may, upon application by a State, establish an average per dwelling unit limitation for dwelling units in such State—

"(i) which conform to program requirements;

"(ii) which, in addition to any other weatherization modifications, have furnace efficiency modifications made under this part; and

"(iii) for which a determination is made pursuant to regulations prescribed by the Secretary that such furnace efficiency modifications are a cost-effective use of funds.

"(B) The average per dwelling unit limitation applicable in a State to units described in subparagraph (A) shall not exceed an amount equal to—

"(i) the amount permitted for the expenditure of financial assistance for labor, weatherization materials, and related matters for dwelling units in such State under paragraphs (1) and (3), plus

"(ii) an amount determined by the Secretary to be the average amount that is appropriate for furnace efficiency modifications of dwelling units of the type assisted under this part in such State.".

TITLE VI—RENEWABLE ENERGY

Subtitle A

SEC. 601. SHORT TITLE.—This subtitle may be cited as the Solar Development Initiative Act of 1989.

SEC. 602. FINDINGS AND PURPOSE.—(a) The Congress finds that—

(1) a diversified and balanced energy resource base is important for the Nation's economic growth;

(2) renewable energy sources, including solar energy, can make a significant contribution toward minimizing the potential for undue dependence on any single energy source;

(3) recent energy trends, including increased imports of foreign oil, increased consumption of petroleum and declining domestic production of petroleum, have reaffirmed the importance of continued Federal support for, and encouragement of, solar energy technologies; and

(4) the international competitiveness of domestic solar thermal and photovoltaics industries depends upon maintaining our technological lead and providing development and marketing assistance to exporters of solar technologies.

(b) PURPOSE.—The purpose of this subtitle is to—

(1) establish multiyear funding levels for a Federal solar research and development program that will maintain current efforts and provide funding stability; and

(2) reaffirm existing Federal policies and establish new policies which promote and encourage investments

in solar energy technologies by the private and public sectors.

SEC. 603. SOLAR AND RENEWABLE ENERGY RESEARCH PROGRAM.—(a) The Secretary of Energy is directed to consult with the solar energy industry to develop a complimentary program of solar and renewable research, development, and demonstration project which—

(1) have near-term commercial applications; and

(2) will enhance the international competitiveness of the solar and renewable energy industries.

(b) The Secretary shall include the funding necessary to implement this program in the fiscal year 1991 budget.

FEDERAL SOLAR BUILDINGS DEMONSTRATION PROGRAM

SEC. 604. (a) PROGRAM SUCCESSFULLY IMPLEMENTED.—Congress finds that the Secretary of Energy, in consultation with the Administrator of the General Services Administration, has successfully implemented a program to demonstrate in Federal buildings the application of solar heating and solar heating and cooling technology pursuant to part 2 of title V of the National Energy Conservation Policy Act (Public Law 95–619).

(b) INFORMATION ABOUT FEDERAL SOLAR BUILDINGS PROGRAM.—In order to more widely disseminate information about the Federal solar buildings program and the benefits of solar heating and solar heating and cooling technology, the Secretary of Energy shall establish a program to dissemi-

nate such information for Federal procurement officers and Federal loan officers which shall include site visits and technical briefings. The Secretary shall utilize existing funds for this program.

INTERNATIONAL MARKET ENHANCEMENT

SEC. 605. (a) CONTINUATION OF ACTIVITIES BY THE COMMITTEE ON RENEWABLE ENERGY, COMMERCE, AND TRADE.—The Committee on Renewable Energy, Commerce, and Trade established by section 256(d) of the Energy Policy and Conservation Act (42 U.S.C. 6271 et seq.) shall continue its activities to coordinate the actions and programs of the Federal Government affecting commerce in renewable energy products and services.

(b) COMMERCE PROGRAMS.—It is the sense of the Congress that the programs established by the Secretary of Commerce under section 256(c)(1) of the Energy Policy and Conservation Act should be funded through the Department of Energy at a minimum of $1,500,000 in fiscal years 1991, 1992, and 1993.

(c) AMENDMENT TO CARIBBEAN BASIN ECONOMIC RECOVERY ACT.—Section 212(c)(7) of the Caribbean Basin Economic Recovery Act (97 Stat. 387; 19 U.S.C. 2703(c)(7)) is amended to read as follows—

"(7) the degree to which such country is undertaking self-help measures to promote its own economic

development and energy self-sufficiency using locally available renewable resources;".

FEDERAL PROCUREMENT

SEC. 606. (a) SECRETARY OF DEFENSE.—Section 2857(b)(1) of title 10, United States Code, is amended by inserting after "has the potential for" the following: "reduced energy costs".

(b) UTILIZATION OF SOLAR ENERGY BY OTHER FEDERAL AGENCIES.—The Secretary of State, the Secretary of Energy, the Secretary of Housing and Urban Development, the Director of the General Services Administration, and the Commissioner of the United States Postal Service shall require that the design of all new Federal facilities built under their respective jurisdictions shall include consideration of energy systems using solar energy or other renewable forms of energy in those cases in which use of such form of energy has the potential for significant savings of fossil-fuel-derived energy.

SEC. 607. AMENDMENT TO THE EXPORT-IMPORT BANK ACT OF 1945.—Section 7 of the Export-Import Bank Act of 1945 (12 U.S.C. 635e) is amended by adding at the end thereof the following:

"(c) Not less than .025 percent of the loan authority of the Bank shall be available only for solar and renewable energy loans.".

SEC. 608. SPECIAL ACTIVITIES OF THE OVERSEAS PRIVATE INVESTMENT CORPORATION.—Section 234(e) of the Foreign Assistance Act of 1961 is amended—

(1) in the first sentence, by inserting after "cooperatives" the following: "and including the initiation of incentives, grants, and studies for renewable energy and other small business activities"; and

(2) by adding at the end thereof the following new sentence: "Administrative funds may not be made available for incentives, grants, and studies for renewable energy and other small business activities.".

SEC. 609. Amendment to the Small Business Act.—(a) Section 7(1) of the Small Business Act (15 U.S.C. 636(1) is repealed.

(b) Section 7(a)(12) of such Act (15 U.S.C. 636(a)(12) is amended to read as follows:

"(12) The Administrator may provide loans under this subsection to assist any small business concern, including startup, to enable such concern to design architecturally or engineer, manufacture, distribute, market, install, or service energy measures. Proceeds of loans under this paragraph shall not be used for research and development. Not less than .025 percent of the loan authority provided under this subsection shall be available only for loans under this paragraph.

The Administrator shall include a list of solar and renewable energy loans in an annual report to the Congress.".

(c) Section 7(a)(14) of such Act (15 U.S.C. 636(a)(14)) is amended to read as follows:

"(14) The Administrator under this subsection may provide extentions and revolving lines of credit for export purposes to enable small business concerns to develop foreign markets and for preexport financing. No such extention or revolving line of credit may be made for a period or periods exceeding 18 months. A bank or participating lending institution may establish the rate of interest in extensions and revolving lines of credit as may be legal and reasonable. The Administrator shall give due consideration to the export potential of solar and renewable energy products in implementing his authorities under this subsection and shall include a list of solar and renewable energy loan guarantees in an annual report to the Congress.".

Subtitle B

This subtitle may be cited as the "Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989".

SEC. 610. PURPOSE.—It is the purpose of this title to direct the Secretary of Energy, acting in accordance with authority contained in the Federal Non-Nuclear Energy Research and Development Policy Act of 1974 (42 U.S.C.

5901–5920) and other law applicable to the Secretary, to pursue an aggressive national program of research, development, and demonstration of renewable energy technologies in order to ensure a stable and secure future energy supply by—

(1) providing a long-term stable environment for renewable energy technology research and development activities through the establishment of long-term goals and multiyear funding levels;

(2) directing the Secretary to undertake initiatives to hasten the commercialization in the near term of renewable energy technologies; and

(3) fostering collaborative research and development efforts involving the private sector through government support of a vigorous program of innovative joint research and development venture projects.

SEC. 611. DEFINITIONS.—As used in this title the term—

(a) "Secretary" means the Secretary of energy; and

(b) "joint research and development venture" means a joint research and development venture under the National Cooperative Research Act of 1984 (98 Stat. 1815).

NATIONAL GOALS AND MULTIYEAR FUNDING FOR FEDERAL WIND, PHOTOVOLTAICS AND SOLAR THERMAL PROGRAMS

SEC. 612. (a) NATIONAL GOALS.—The following are declared to be the national goals for the wind, photovoltaics and solar thermal energy programs currently being carried out by the Secretary under existing law:

(1) WIND.—(A) In general, the goals for the Wind Energy Research Program include improving design methodologies and developing more reliable and efficient wind turbines to increase the cost competitiveness of wind energy. Research efforts shall emphasize—

(i) activities that address near-term technical problems and permit exploitation of current market opportunities of the wind energy industry;

(ii) developing advanced airfoils and variable speed generators to increase wind and turbine output and reduce maintenance costs by decreasing structural stress and fatigue;

(iii) increasing the basic knowledge of aerodynamics, structural dynamics, fatigue and electrical systems interactions as applied to current wind energy technology; and

(iv) improving the compatibility of electricity produced from windfarms with conventional utility needs.

(B) Specific goals for the Wind Energy Research Program shall be to—

(i) reduce average wind energy costs to 3 to 5 cents per kilowatt hour by 1995;

(ii) reduce capital costs of new wind energy systems to $500 to $750 per kilowatt of installed capacity by 1995;

(iii) increase installed wind generating capacity to 4000 to 8000 megawatts by 1995;

(iv) reduce operation and maintenance costs for wind energy systems to less than 1 cent per kilowatt hour by 2000; and

(v) increase capacity factors for new wind energy systems to 25 to 30 percent by 1995.

(2) PHOTOVOLTAICS.—(A) In general, the goals of the Photovoltaic Energy Systems Program shall include improving the reliability and conversion efficiencies and lowering the costs of photovoltaic conversion. Research efforts shall emphasize advancements in the performance, stability and durability of photovoltaic materials.

(B) Specific goals of the Photovoltaic Energy Systems Program shall be to—

(i) improve operational reliability of photovoltaic modules to 30 years by 1995;

(ii) increase photovoltaic conversion efficiency of new photovoltaic amorphous silicon modules to 15 percent by 1995;

(iii) decrease new photovoltaic module direct manufacturing costs to $800 per kilowatt by 1995; and

(iv) increase installed capacity of photovoltaic electric power production capacity to 100 to 200 megawatts by 1991.

(3) SOLAR THERMAL.—(A) In general, the goal of the Solar Thermal Energy Systems Program shall be to advance research and development to a point where solar thermal technology is cost-competitive with conventional energy sources and to promote the integration of this technology into the production of industrial process heat and the conventional utility network. Research and development shall emphasize development of a thermal storage technology to provide capacity for shifting power to periods of demand when full insulation is not available; improvement in receivers, energy conversion devices, and innovative concen-

trators using stretch membranes, lenses, and other materials; and exploration of advanced manufacturing techniques.

(B) Specific goals of the Solar Thermal Energy Systems Program shall be to—

(i) reduce solar thermal costs for industrial process heat to $9 per million British thermal units; and

(ii) reduce average solar thermal costs for electricity to 4 to 5 cents per kilowatt hour.

(C) The President's budget request for fiscal year 1991 shall contain the Secretary's recommendations for specific cost, installed capacity, and other pertinent goals for 1995 for Department of Energy research, development, and demonstration programs in Biofuels Energy Systems, Solar Buildings Energy Systems, Ocean Energy Systems, and Geothermal Energy.

(b) AMENDED GOALS.—Whenever the Secretary determines that any of the goals established under this section are no longer appropriate, he shall notify Congress of the reason for the determination and provide an amended goal that is consistent with the purposes of this title.

(c) AUTHORIZATIONS.—There is authorized to be appropriated to the Secretary—

(1) for the Wind Energy Research Program, an amount not to exceed $19,000,000 in fiscal year 1991; $22,000,000 in fiscal year 1992; and $26,000,000 in fiscal year 1993;

(2) for the Photovoltaic Energy Systems Program, an amount not to exceed $43,100,000 in fiscal year 1991; $45,000,000 in fiscal year 1992; and $50,000,000 in fiscal year 1993;

(3) for the Solar Thermal Energy Systems Program, an amount not to exceed $28,700,000 in fiscal year 1991; $32,000,000 in fiscal year 1992; and $35,000,000 in fiscal year 1993;

(4) for the Biofuels Energy Systems Program, an amount not to exceed $32,100,000 in fiscal year 1991; $35,100,000 in fiscal year 1992; and $40,000,000 in fiscal year 1993;

(5) for the Solar Buildings Energy Systems Program, an amount not to exceed $8,000,000 in fiscal year 1991; $9,000,000 in fiscal year 1992; and $10,000,000 in fiscal year 1993;

(6) for the Ocean Energy Systems Program, an amount not to exceed $5,000,000 in fiscal year 1991; $5,000,000 in fiscal year 1992; and $5,000,000 in fiscal year 1993; and

(7) for the Geothermal Program, an amount not to exceed $34,900,000 in fiscal year 1991; $35,700,000 in fiscal year 1992; and $38,700,000 in fiscal year 1993.

(d) REPORT ON OPTIONS.—On or before May 1, 1991, the Secretary shall submit to Congress a report analyzing options available to the Secretary under existing law to accelerate the timely commercialization of wind, photovoltaic, solar thermal, biofuels, biomass, solar buildings, ocean and goethermal renewable energy technologies through emphasis on development and demonstration assistance to specific technologies in the research, development, and demonstration programs of the Department of Energy that are near commercial application.

JOINT RESEARCH AND DEVELOPMENT VENTURES

SEC. 614. (a) FINDINGS.—For purposes of this section, Congress finds that joint research and development ventures can—

(1) improve coordination in technology development among firms in industries attempting to commercialize renewable energy technologies;

(2) assist in setting national standards to improve the operation of markets for these technologies; and

(3) enhance the ability of domestic firms to compete with foreign enterprises in sales of renewable energy technologies.

(b) PURPOSE.—The purpose of this section is to direct the Secretary of Energy to make use of joint research and development ventures to further commercialization of renewable energy technologies.

(c) ESTABLISHMENT.—(1) The Secretary shall establish seven joint research and development ventures in accordance with the provisions of this section. Each joint research and development venture under this section shall include manufacturing firms, investors, an advisory committee appointed in accordance with this section, and such other participation as the Secretary deems appropriate to achieve the purposes of this section. Any facilities constructed under this section shall be located in the United States, Puerto Rico, the Virgin Islands, or the territories and possessions of the United States.

(2) The Secretary shall require that at least 30 percent of all costs of any joint research and development venture under this section be provided from non-Federal sources.

(3) Before establishing the joint research and development ventures under paragraph (1), the Secretary shall consult with, and take into consideration the recommendations of, the Advisory Committee on Renewable Energy and Energy Efficiency Technology under paragraph (4).

(4)(A) The Secretary shall appoint members to an Advisory Committee on Renewable Energy and Energy Efficiency Technology (hereafter referred to as the "Advisory Com-

mittee") to assist the Secretary in carrying out his responsibilities under this section. The Advisory Committee shall include at least one member representing each of the following—

(i) the Secretary of Commerce;

(ii) the Secretary of Housing and Urban Development;

(iii) the Solar Energy Research Institute;

(iv) the Electric Power Research Institute;

((v) the National Institute of Building Sciences;

(vi) associations of firms in each of the major renewable energy manufacturing industries; and

(vii) associations of firms in each of the major energy efficiency manufacturing industries.

(B) The Advisory Committee, within 120 days after its formation, provide the Secretary with recommendations for the establishment of joint ventures under paragraph (1) and shall advise the Secretary from time to time about the implementation of such ventures. Recommendations of the Advisory Committee shall be available to the public.

(5) The Secretary shall establish at least one joint research and development venture in accordance with subsection (d) to develop technology and expertise in each of the following areas—

(A) photovoltaics technology;

(B) wind energy technology;

(C) solar thermal technology;

(D) factory-made housing;

(E) advanced district cooling technology;

(F) renewable energy and energy efficiency technology exports; and

(G) fuel cell energy systems.

(6) Not later than 180 days after the date of the enactment of this section the Secretary shall publish plans to implement this section and report to Congress on such plans.

(d) VENTURE.—(1) PHOTOVOLTAICS TECHNOLOGY.—

(A) The Secretary shall establish and provide financial assistance to a joint research and development venture for the demonstration of photovoltaic conversion of solar energy in accordance with the provisions of this paragraph.

(B) The purpose of the venture under subparagraph (A) shall be to design, test and demonstrate systems employing critical enabling technologies for photovoltaic conversion of solar energy so as to achieve, to the maximum extent practicable, the goals of the Photovoltaic Energy Systems Program set forth in section 613(a)(2), as those goals may be amended under section 613(b). The venture under this paragraph may emphasize production, distribution, storage, or end use of

electricity from photovoltaic conversion of solar energy or any combination thereof.

(C) In soliciting proposals for the joint research and development venture under this paragraph, the Secretary shall consider the recommendations of the Advisory Subcommittee on Photovoltaic Energy Technology under subparagraph (D).

(D) The Secretary shall appoint members to an Advisory Subcommittee on Photovoltaic Energy Technology to assist the Secretary in carrying out his responsibilities with respect to the joint venture under this paragraph. Such subcommittee shall include such members of the Advisory Committee as the Secretary deems appropriate and, in addition, at least one member representing each of the following—

(i) firms in the photovoltaic manufacturing industry;

(ii) the Director of the Agency for International Development; and

(iii) the Director of the Export-Import Bank.

(E) There is authorized to be appropriated to the Secretary a total of not more than $1,200,000 for each of the fiscal years 1991, 1992, and 1993 to carry out the purposes of this paragraph.

(2) WIND ENERGY TECHNOLOGY.—(A) The Secretary shall establish and provide financial assistance to a joint research and development venture for the demonstration of the conversion of wind energy in accordance with the provisions of this paragraph.

(B) The purpose of the venture under subparagraph (A) shall be to design, test and demonstrate systems employing critical enabling technologies for the conversion of wind energy so as to achieve, to the maximum extent practicable, the goals of the Wind Energy Research Program set forth in section 613(a)(1), as those goals may be amended under section 613(e). The venture under this paragraph may emphasize production, distribution, storage, or end use of wind energy or any combination thereof and may include systems employing other sources of energy in addition to wind energy.

(C) In soliciting proposals for the joint research and development venture under this paragraph, the Secretary shall consider the recommendations of the Advisory Subcommittee on Wind Energy Technology under subparagraph (D).

(D) The Secretary shall appoint members to an Advisory Subcommittee on Wind Energy Technology to assist the Secretary in carrying out his responsibilities with respect to the joint venture under this paragraph. Such subcommittee shall include such members of the Advisory Committee as the

Secretary deems appropriate and, in addition, at least one member representing each of the following—

(i) firms in the wind energy equipment manufacturing industry;

(ii) the Director of the Agency for International Development; and

(iii) the Director of the Export-Import Bank.

(E) There is authorized to be appropriated to the Secretary a total of not more than $1,200,000 for each of the fiscal years 1991, 1992, and 1993 to carry out the purposes of this paragraph.

(3) SOLAR THERMAL TECHNOLOGY.—(A) The Secretary shall establish and provide financial assistance to a joint research and development venture for the demonstration of the use of solar thermal energy in accordance with the provisions of this paragraph.

(B) The purpose of the venture under subparagraph (A) shall be to design, test and demonstrate critical enabling technologies for the use of solar thermal energy so as to achieve, to the maximum extent practicable, the goals of the Solar Thermal Energy Systems Program set forth in section 613(a)(3), as those goals may be amended under section 613(b). The venture under this paragraph may emphasize production, distribution, storage, or end use of solar thermal energy or any combination thereof and may include systems

employing other sources of energy in addition to solar thermal energy.

(C) In soliciting proposals for the joint research and development venture under this paragraph, the Secretary shall consider the recommendations of the Advisory Subcommittee on Solar Thermal Energy Technology under subparagraph (D).

(D) The Secretary shall appoint members to an Advisory Subcommittee on Wind Energy Technology to assist the Secretary in carrying out his responsibilities with respect to the joint venture under this paragraph. Such subcommittee shall include such members of the Advisory Committee as the Secretary deems appropriate and, in addition, at least one member representing each of the following—

(i) firms in the solar thermal manufacturing industry;

(ii) the Director of the Agency for International Development;

(iii) the Director of the Export-Export Bank; and

(iv) the Gas Research Institute.

(E) There is authorized to be appropriated to the Secretary a total of not more than $900,000 for each of the fiscal years 1991 through 1993 to carry out the purposes of this paragraph.

(4) FACTORY MADE HOUSING.—(A) The Secretary shall establish and provide financial assistance to a joint research and development venture with such specialized private firms and investors as the Secretary deems appropriate in order to establish at last 3 regional projects to demonstrate techniques to improve the energy performance of factory-made housing offered by United States firms. In locating the projects under this paragraph, the Secretary shall consider regional differences in housing needs, housing design, construction technique, marketing practices, and construction materials.

(B) The projects under this paragraph shall be designed to demonstrate state-of-the-art product quality, energy efficiency, and adaptability to renewable forms of energy of factory-made housing offered for sale in the United States. The projects shall be structured to demonstrate improvements in housing design, fabrication, delivery systems, construction processes, marketing, and product export techniques.

(C) The demonstration strategy under this paragraph shall be guided by—

(i) a detailed characterization of the needs of the home building industry;

(ii) a close working relationship with all sectors of the home building industry; and

(iii) coordination among the projects to pool and conserve resources.

(D) In selecting projects under this section, the Secretary shall consider the recommendations of the Advisory Subcommittee on Energy Performance in Factory-Made Housing established under subparagraph (E).

(E) The Secretary shall appoint members to an Advisory Subcommittee on Energy Performance in Factory-Made Housing to assist the Secretary in carrying out his responsibilities with respect to the joint research and development venture established under this paragraph. Such subcommittee shall include such members of the Advisory Committee as the Secretary deems appropriate and, in addition, at least one member representing each of the following—

(i) the National Association of Home Builders;

(ii) the National Laboratories of the Department of Energy; and

(iii) the National Institute of Standards and Technology.

(F) There is authorized to be appropriated to the Secretary a total of not more than than $5,000,000 for each of the fiscal years 1991 through 1993 to carry out the purposes of this paragraph.

(5) ADVANCED DISTRICT COOLING TECHNOLOGY.—(A)(i) The Secretary shall establish and provide financial as-

sistance to a joint research and development venture with such specialized private firms and investors as the Secretary deems appropriate in order to develop advanced district cooling technologies that are applicable in cities with high cooling loads.

(ii) The purpose of the joint venture under this paragraph is to develop technical strategies for decreasing the capital cost and increasing the energy efficiency of major district heating and cooling system components and to assist in making district heating and cooling available to local governments.

(B) The Secretary shall select 3 cities for application of advanced district cooling technologies developed by the joint venture under this paragraph. The activities to be carried out in such application shall include district cooling assessment, feasibility, and engineering design studies.

(C) In selecting the cities under subparagraph (B), the Secretary shall consider the recommendations of the Advisory Subcommittee on Advanced District Cooling Technology established under subparagraph (D).

(D) The Secretary shall appoint members to an Advisory Subcommittee on Advanced District Cooling Technology to assist the Secretary in carrying out his responsibilities with respect to the joint research and development venture under this paragraph. Such subcommittee shall include such

members of the Advisory Committee as the Secretary deems appropriate and, in addition, at least one member representing each of the following—

(i) firms manufacturing district cooling equipment; and

(ii) the National League of Cities.

(E) There is authorized to be appropriated for each of the fiscal years 1991 through 1993 not more than $1,000,000 per year to carry out the purposes of this paragraph.

(6) EXPORT TECHNOLOGY PROJECTS.—(A) For purposes of this paragraph Congress finds that—

(i) the United States has several advanced energy efficiency and renewable energy technologies that lack only sufficient coordination, support, and emphasis to become important export items capable of reducing the United States' trade deficit;

(ii) a major barrier to export of energy efficiency and renewable energy technology is the lack of information on overseas markets and technology development by foreign competitors;

(iii) the industry that markets energy efficiency technology is highly fragmented, and the renewable energy industry is comprised of small firms that lack

the necessary resources to identify and target overseas markets; and

(iv) a joint research and development venture is needed to bring together a broad array of manufacturing firms, financial institutions, and Federal agencies to identify and develop promising technologies and export markets for energy efficiency and renewable energy technologies.

(B) The Secretary shall establish and provide financial assistance to a joint research and development venture with such specialized private firms and investors as the Secretary determines appropriate for the purpose of commercializing and marketing domestically-developed energy efficiency and renewable energy technologies in order to enhance sales of products developed from such technologies relative to foreign-made products.

(C) In designing the joint venture under subparagraph (B), the Secretary shall consider the recommendations of the Advisory Subcommittee on Renewable Energy and Energy Efficiency Technology Exports established under subparagraph (D).

(D) The Secretary shall appoint members to an Advisory Subcommittee on Renewable Energy and Energy Efficiency Technology Exports to assist the Secretary in carrying out his responsibilities with respect to the joint research and

development venture under this paragraph. Such subcommittee shall include such members of the Advisory Committee as the Secretary deems appropriate and, in addition, at least one member representing each of the following—

(i) the Director of the Agency for International Development;

(ii) the Director of the Export-Import Bank;

(iii) the United States Export Council for Renewable Energy;

(iv) the National Laboratories of the Department of Energy.

(E) There is authorized to be appropriated to the Secretary to carry out the purposes of this paragraph a total amount for each of the fiscal years 1991 through 1993 not to exceed $5,000,000 with respect to renewable energy activities under this paragraph and $5,000,000 with respect to energy efficiency activities under this paragraph.

(e) SECRETARIAL DISCRETION.—(1) If the Secretary, based on the recommendations of the Advisory Committee under subsection (c)(4)(B) with respect to a joint research and development venture described under subsection (d), determines, in consultation with the Advisory Committee, that—

(A) there is insufficient private sector interest in such venture to satisfy the requirement of subsection (c)(2);

(B) carrying out the venture will not further the purposes of this title; or

(C) timely commercialization of the technology to be demonstrated will not be advanced by the venture,

then the Secretary shall not be subject to the requirements of subsection (d) with respect to the technology to be demonstrated by the joint research and development venture.

(2) The Secretary shall notify Congress of any determination under paragraph (1) and provide a written explanation of the reasons for the determination. Immediately thereafter, the Secretary shall consult with the Advisory Committee, and, based on the recommendations of such Committee, shall promptly transmit to Congress a plan for the establishment of a substitute joint research and development venture to demonstrate, consistent with this section, an alternative renewable energy or energy efficiency technology so as to accomplish the purposes of this title. Any unexpended funds authorized to be appropriated under subsection (d) for the joint research and development venture with respect to which a determination is made under paragraph (1) may be used for a substitute joint research and development venture established under this subsection.

(3) When 30 calendar days have elapsed after transmittal of the plan under paragraph (2), the Secretary shall pro-

ceed with the joint research and development venture described in his plan as is such venture were required under subsection (d).

(f) ADDITIONAL COMMERCIALIZATION PROJECTS.—(1) The President's budget request for fiscal year 1992 shall include the Secretary's recommendations for at least one proposed proof-of-concept on near-commercial demonstration project in each of the categories represented by section 3(a) (1), (2), and (3). Each proposed project shall be described in sufficient detail to support congressional authorization and solicitation of bids for construction of necessary facilities.

(2) A list and description of alternative project plans under this subsection shall be submitted in President's fiscal year 1991 budget request. Such plans shall require funding or in-kind contributions from private sources in support of at least 30 percent of total project costs.

(3) In selecting proposed projects under this subsection, the Secretary shall take into account the extent to which such projects will contribute to earlier commercialization of key technologies within such categories that might occur without Federal support under this subsection and the extent to which such projects will contribute to the competitiveness of United States firms engaged in international trade in renewable energy technologies.

RENEWABLE ENERGY EXPORTS

SEC. 615. (a) FINDINGS AND PURPOSES.—(1) for purposes of this section, Congress finds that—

(A) among the major problems in promoting exports of renewable energy technology are the lack of available information on overseas markets and the absence of financing for the purchase of the technologies; and

(B) the Committee on Renewable Energy, Commerce, and Trade ("CORECT") established under the Renewable Energy Industry Development Act (Public Law 98-370) currently coordinates Federal Government activities to promote renewable energy exports.

(2) The purpose of this section is to evaluate current efforts to promote exports of renewable energy technology, to establish a joint government-industry plan to identify promising technologies and increase the financing available for exports of renewable energy technologies, to target potential markets for these technologies, and to authorize funding of these activities.

(b) ANNUAL REPORT.—The Committee on Renewable Energy, Commerce, and trade shall annually report to Congress.

(c) AGENCY ACTIONS.—Each report submitted under subsection (b) shall describe the actions of each agency repre-

sented by a member of the Committee on Renewable Energy, Commerce, and Trade taken during the previous fiscal year to achieve the purposes of such committee and of this section. Such report shall describe the exports of renewable energy technology that have occurred as a result of such agency actions.

(d) PLAN.—The Committee on Renewable Energy, Commerce, and Trade shall—

(1) establish a joint government-industry plan to maintain or increase the market share of the United States in international trade in renewable energy technologies, including technologies for production of alcohol fuels, biomass energy, geothermal energy, wood energy, and in technologies for fuel cell energy conversion, passive solar energy conversion, photovoltaics, solar thermal energy conversion, and wind energy conversion. Such plan shall include guidelines for agencies that are members of the committee with respect to the financing of exports of such renewable energy technologies;

(2) develop, in consultation with representatives of affected industries, administrative guidelines for Federal export loan programs to simplify application by firms seeking export assistance for renewable energy tech-

nologies from agencies implementing such programs; and

(3) target renewable energy technology markets for primary emphasis by Federal export loan programs, development programs, and private sector assistance programs.

(e) The Committee on Renewable Energy, Commerce, and Trade shall include a description of the plan under paragraph (1) in no later than the second report submitted under subsection (b), and shall include in subsequent reports a description of any modifications to such plan and of the progress in implementing the plan.

(f) AUTHORIZATIONS.—There is hereby authorized to be appropriated to the Secretary for activities of the Committee on Renewable Energy, Commerce, and Trade an amount not to exceed—

(1) $1,200,000 in fiscal year 1991;

(2) $1,500,000 in fiscal year 1992; and

(3) $1,800,000 in fiscal year 1993.

RENEWABLE ENERGY

SEC. 616. (a) DISSEMINATION OF INFORMATION.—Section 523 of the National Energy Conservation Policy Act (42 U.S.C. 8243) is amended by adding a new subsection (d) as follows:

"(d) In order to more widely disseminate information about the program under this part and under part 3 and the

benefits of solar heating and solar heating and cooling technology, the Secretary shall establish a program to disseminate such information for Federal procurement officers and Federal loan officers that shall include site visits and technical briefings. The Secretary shall utilize available funds for the program under this subsection.".

(b) DEPARTMENT OF DEFENSE HOUSING.—Section 2857(b)(1) of title 10, United States Code, is amended by inserting after 'has the potential for' the following: "reduced energy costs".

(c) OVERSEAS PRIVATE INVESTMENT CORPORATION LOANS.—Section 234(e) of the Foreign Assistance Act of 1961 is amended—

(1) in the first sentence, by inserting after 'cooperatives' the following: "and including the initiation of incentives, grants, and studies for renewable energy and other small business activities"; and

(2) by adding at the end thereof the following new sentence: "Administrative funds may not be made available for incentives, grants, and studies for renewable energy and other small business activities.".

REPORTS

SEC. 617. (a) REPORT BY THE SECRETARY.—One year after the date of the enactment of this title and annually thereafter, the Secretary shall report to Congress on the programs, projects, and joint research and development ventures

conducted under this title and the progress being made towards accomplishing the goals and purposes set forth in this title, including the national goals set forth in section 613(a).

(b) NATIONAL ENERGY POLICY PLAN REPORT.—Each annual submission of the National Energy Policy Plan under title VIII of Public Law 95–91 shall be accompanied by a 3-year strategic plan for energy technology research, development, and demonstration. Such plan shall address the role of federally assisted research, development, and demonstration projects in the achievement of the national policy goals of the National Energy Policy Plan and shall assess both the level of support for energy research, development, and demonstration reasonably necessary to achieve these goals and the basis for allocating the support recommended by the President among the available alternatives. At a minimum, these alternatives shall include energy efficiency and renewable energy technologies.

Subtitle C

RENEWABLE ENERGY/FUEL CELL SYSTEMS INTEGRATION AND UTILIZATION

SEC. 618. FINDINGS.—The Congress finds that—(a) while the Federal Government has invested substantially in fuel cell technology through research and development during the past 10 years, additional research on technologies that enable fuel cells to use alternative fuel sources needs to be

undertaken in order to fulfill the conservation promise of fuel cells as an energy source;

(b) there is no national policy for acting upon the findings of this research and development; and

(c) if such a national policy were developed, the public investment in fuel cell technology would be realized through reduced dependency on imported oil and the subsequent improvement in the international trade accounts of the United States.

RESEARCH PROGRAMS

SEC. 619. (a) PROGRAM AUTHORIZATION.—The Secretary shall implement and carry out a research program for the purposes of—

(1) exploring the operation of fuel cells employing methane gas generated from various forms of biomass;

(2) developing technologies to use renewable energy sources, including wind and solar energy, to produce hydrogen for use in fuel cells; and

(3) determining the technical requirements for employing fuel cells for electric power production as backup spinning reserve components to renewable power systems in rural and isolated areas.

(b) GRANTS.—In carrying out the research program authorized in subsection (a), the Secretary may make grants to, or enter into contracts, private research laboratories.

(c) REPORT TO CONGRESS.—The Secretary shall transmit to the Congress on or before September 30, 1991, a comprehensive report on research carried out pursuant to this Act.

(d) AUTHORIZATION.—There are hereby authorized to be appropriated $5,000,000 for fiscal year 1991 to the Secretary to be used to conduct research as provided in this Act.

SEC. 620. INCLUSION OF FUEL CELLS AS A FUEL CONSERVATION TECHNOLOGY UNDER REIDA.—Section 256 of the Energy Policy and Conservation Act is amended by inserting at the end thereof the following:

"(e) For purposes of this section, the term 'domestic renewable energy industry' shall include industries using fuel cell technology.".

SEC. 621. ENVIRONMENTAL PROTECTION AGENCY GUIDELINES FOR THE USE OF FUEL CELL TECHNOLOGIES.—Within 180 days of the date of enactment of this Act, the Administrator of the Environmental Protection Agency shall prepare Federal guidelines for cities and municipalities specifying environmental and safety standards for the use of fuel cell technology. In the preparation of the guidelines, the Administrator shall utilize the successful experience of the New York City Fire Department in the use of fuel cell technologies.

SEC. 622. DEPARTMENT OF COMMERCE INVESTIGATION OF EXPORT MARKET POTENTIAL FOR INTEGRATED FUEL CELL SYSTEMS.—Within 180 days of the date of enactment of this Act, the Secretary of Commerce shall assess and report to Congress concerning the export market potential for integrated systems of fuel cells with renewable power technologies.

Subtitle D

HYDROGEN RESEARCH AND DEVELOPMENT ACT

SEC. 623. FINDINGS AND PURPOSE.—(a) The Congress finds that—

(1) due to the limited quantities of naturally occuring petroleum-based fuels, viable alternative fuels and feedstocks must be developed;

(2) priority should be given to the development of alternative fuels with universal availability;

(3) hydrogen is one of the most abundant elements in the universe, with water, a primary source of hydrogen, covering three-fourths of the Earth;

(4) hydrogen appears promising as an alternative to environmentally damaging fossil fuels;

(5) hydrogen can be transported more efficiently and at less cost then electricity over long distances;

(6) renewable energy resources are potential energy sources that can be converted to hydrogen from

its naturally occurring states into high quality fuel, feedstock, and energy storage media; and

(7) it is in the national interest to accelerate efforts to develop a domestic capability to economically produce hydrogen in quantities which will make a significant contribution toward reducing the Nation's dependence on conventional fuels.

(b) The purpose of this title is to—

(1) direct the Secretary of Energy to prepare and implement a comprehensive 5-year plan and program to accelerate research and development activities leading to the realization of a domestic capability to produce, distribute, and use hydrogen economically within the shortest time practicable; and

(2) develop renewable energy resources as primary energy sources to be used in the production of hydrogen.

COMPREHENSIVE MANAGEMENT PLAN

SEC. 624. (a) The Secretary shall prepare a comprehensive 5-year program management plan for research and development activities which shall be conducted over a period of no less than 5 years and shall be consistent with the provisions of sections 625 and 626. In the preparation of such plan, the Secretary shall consult with the Administrator of the National Aeronautics and Space Administration, the Secretary of Transportation, the Hydrogen Technical Advisory

Panel established under section 628, and the heads of such other Federal agencies and such public and private organizations as he deems appropriate. Such plan shall be structured to permit the realization of a domestic hydrogen production capability within the shortest time practicable.

(b) The Secretary shall transmit the comprehensive program management plan to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Energy and Natural Resources of the Senate within 6 months after the date of the enactment of this Act—

(1) the research and development priorities and goals to be achieved by the program;

(2) the program elements, management structure, and activities, including program responsibilities of individual agencies and individual institutional elements;

(3) the program strategies including technical milestones to be achieved toward specific goals during each fiscal year for all major activities and projects;

(4) the estimated costs of individual program items, including current as well as proposed funding levels for each of the 5 years of the plan for each of the participating agencies;

(5) a description of the methodology of coordination and technology transfer; and

(6) the proposed participation by industry and academia in the planning and implementation of the program.

(c) Concurrently with the submission of the President's annual budget to the Congress for each year after the year in which the comprehensive 5-year plan is initially transmitted under subsection (b), the Secretary shall transmit to the Congress a detailed description of the current comprehensive plan, setting forth appropriate modifications which may be necessary to revise the plan as well as comments on, and recommendations for, improvements in the comprehensive program management plan made by the Hydrogen Technical Advisory Panel established under section 628.

RESEARCH AND DEVELOPMENT

SEC. 625. (a) The Secretary shall establish, within the Department of Energy, a research and development program, consistent with the comprehensive 5-year management plan under section 624, to ensure the development of a domestic hydrogen fuel production capability within the shortest time practicable.

(b)(1) The Secretary shall initiate research or accelerate existing research in areas which may contribute to the development of hydrogen production and use.

(2) Areas researched shall include production, liquefaction transmission, distribution, storage, and use. Particular attention shall be given to developing an understanding and

resolution of all potential problems of introducing hydrogen production and use into the marketplace.

(c) The Secretary shall give priority to those production techniques that use renewable energy resources as their primary energy source.

(d) The Secretary shall, for the purpose of performing his responsibilities pursuant to this title, solicit proposals for and evaluate any reasonable new or improved technology, a description of which is submitted to the Secretary in writing, which could lead or contribute to the development of hydrogen production technology.

(e) The Secretary shall conduct evaluations, arrange for tests and demonstrations, and disseminate to developers information, data, and materials necessary to support efforts undertaken pursuant to this section.

DEMONSTRATIONS AND PLAN

SEC. 626. (a)(1) The Secretary shall conduct demonstrations of hydrogen technology, preferably in self-contained locations, so that technical and nontechnical parameters can be evaluated to best determine commercial applicability of the technology.

(2) Concurrently with activities conducted pursuant to section 624, the Secretary shall conduct small-scale demonstrations of hydrogen technology at self-contained sites.

(b) The Secretary shall, in consultation with the Secretary of Transportation, the Administrator of the National

Aeronautics and Space Administration, and Hydrogen Technical Advisory Panel established under section 628, prepare a comprehensive large-scale hydrogen demonstration plan with respect to demonstrations carried out pursuant to subsection (a)(1). Such plan shall include—

(1) a description of the necessary research and development activities that must be completed before initiation of a large-scale hydrogen production demonstration program;

(2) an assessment of the appropriateness of a large-scale demonstration immediately upon completion of the necessary research and development activities; and

(3) an implementation schedule with associated budget and program management resource requirements.

COORDINATION AND CONSULTATION

SEC. 627. (a) The Secretary shall have overall management responsibility for carrying out the program under this title. In carrying out such program, the Secretary, consistent with such overall management responsibility—

(1) shall use the expertise of the National Aeronautics and Space Administration and the Department of Transportation; and

(2) may use the expertise of any other Federal agency in accordance with subsection (b) in carrying

out any activities under this title, to the extent that the Secretary determines that any such agency has capabilities which would allow such agency to contribute to the purpose of this title.

(b) The Secretary may, in accordance with subsection (a), obtain the assistance of any department, agency or instrumentality of the executive branch of the Federal Government upon written request, on a reimbursable basis or otherwise and with the consent of such department, agency, or instrumentality. Each such request shall identify the assistance the Secretary deems necessary to carry out any duty under this title.

(c) The Secretary shall consult with the Administrator of the National Aeronautics and Space Administration, the Administrator of the Environmental Protection Agency, the Secretary of Transportation, and the Hydrogen Technical Advisory Panel established under section 628 in carrying out his authorities pursuant to this title.

TECHNICAL PANEL

SEC. 628. (a) There is hereby established a technical panel of the Energy Research Advisory Board, to be known as the Hydrogen Technical Advisory Panel, to advise the Secretary on the program under this title.

(b)(1) The technical panel shall be appointed by the Secretary and shall be comprised of such representatives from domestic industry, universities, professional societies, Gov-

ernment laboratories, financial, environmental, and other organizations as the Secretary, in consultation with the Chairman of the Energy Research Advisory Board, deems appropriate based on his assessment of the technical and qualifications of such representatives. Appointments to the technical panel shall be made within 90 days after the enactment of this Act. The technical panel shall have a chairman, who shall be elected by the members from among their number.

(2) Members of the technical panel need not be members of the full Energy Research Advisory Board.

(c) The activities of the technical panel shall be in compliance with any laws and regulations guiding the activities of technical and factfinding groups reporting to the Energy Research Advisory Board.

(d) The heads of the departments, agencies, and instrumentalities of the executive branch of the Federal Government shall cooperate with the technical panel in carrying out the requirements of this section and shall furnish to the technical panel such information as the technical panel deems necessary to carry out this section.

(e) The technical panel shall review and make any necessary recommendations to the following items, among others—

(1) the implementation and conduct of the program under this title; and

(2) the economic, technological, and environmental consequences of the deployment of hydrogen production and use systems.

(f) The technical panel shall prepare and submit annually to the Energy Research Advisory Board a written report of its findings and recommendations with regard to the program under this title. The report shall include—

(1) a summary of the technical panel's activities for the preceding year;

(2) an assessment and evaluation of the status of the program; and

(3) comments on and recommendations for improvements in the comprehensive 5-year program management plan required under section 624.

(g) After consideration of the technical panel report and within 30 days after its receipt, the Energy Research Advisory Board shall submit the report, together with any comments which the Board deems appropriate, to the Secretary.

(h) The Secretary shall provide such staff, funds, and other support as may be necessary to enable the technical panel to carry out the functions described in this section.

DEFINITIONS

SEC. 629. As used in this title—

(a) the term "Secretary" means the Secretary of Energy; and

(b) the term "capability" means proven technical ability.

AUTHORIZATION OF APPROPRIATIONS

SEC. 630. There is hereby authorized to be appropriated to carry out the purpose of this title (in addition to any amounts made available for such purpose pursuant to other Acts)—

(a) $10,000,000 for the fiscal year beginning October 1, 1991;

(b) $15,000,000 for the fiscal year beginning October 1, 1992;

(c) $20,000,000 for the fiscal year beginning October 1, 1993;

(d) $25,000,000 for the fiscal year beginning October 1, 1994;

(e) $30,000,000 for the fiscal year beginning October 1, 1995;

HYDROGEN-FUELED AIRCRAFT RESEARCH AND DEVELOPMENT

SEC. 631. FINDINGS AND PURPOSE.—(a) The Congress finds that—

(1) long-term future decreases in petroleum-based fuel availability will seriously impair the operation of the world's air transport fleets;

(2) hydrogen appears to be an attractive alternative to petroleum in the long-term to fuel commercial aircraft;

(3) it is therefore in the national interest to accelerate efforts to develop a domestic hydrogen-fueled supersonic and subsonic aircraft capability; and

(4) the use of liquid hydrogen as a commercial air transport fuel has sufficient long-term promise to justify a substantial research, development demonstration program.

(b) The purpose of this title is to—

(1) direct the Administrator of the National Aeronautics and Space Administration to prepare and implement a comprehensive 5-year plan and program for the conduct of research, development, and demonstration activities leading to the realization of a domestic hydrogen-fueled aircraft capability within the shortest time practicable;

(2) establish as a goal broad multinational participation in the program; and

(3) provide a basis for public, industry, and certifying agency acceptance of hydrogen-fueled aircraft as a mode of commercial air transport.

COMPREHENSIVE MANAGEMENT PLAN

SEC. 632. (a) The Administrator shall prepare a comprehensive 5-year program management plan for research,

development, and demonstration activities consistent with the provisions of sections 633, 634, and 635. In the preparation of such plan, the Administrator shall consult with the Secretary of Energy, the Secretary of Transportation, and the heads of such other Federal agencies and such public and private organizations as he deems appropriate. Such plan shall be structured to permit the realization of a domestic hydrogen-fueled aircraft capability within the shortest time practicable.

(b) The Administrator shall transmit the comprehensive 5-year program management plan to the Committee on Science, Space, and Technology of the House of Representatives and the Committees on Commerce, Science, and Transportation and Energy and Natural Resources of the Senate within 6 months after the date of the enactment of this Act. The plan shall include, but not necessarily be limited to—

(1) the research and development priorities and goals to be achieved by the program;

(2) the program elements, management structure, and activities, including program responsibilities of individual agencies and individual institutional elements;

(3) the program strategies including detailed technical milestones to be achieved toward specific goals during each fiscal year for all major activities and projects;

(4) the estimated costs of individual program items, including current as well as proposed funding levels for each of the 5 years of the plan for each of the participating agencies;

(5) a description of the methodology of coordination and technology transfer; and

(6) the proposed participation by industry and academia in the planning and implementation for the program.

(c) Concurrently the submission of the President's annual budget to the Congress for each year after the year in which the comprehensive 5-year plan is initially transmitted under subsection (b), the Administrator shall transmit to the Congress a detailed description of the current comprehensive plan, setting forth appropriate modifications which may be necessary to revise the plan as well as comments on and recommendations for improvements in the comprehensive program management plan made by the Hydrogen-Fueled Aircraft Advisory Committee established under section 637.

RESEARCH AND DEVELOPMENT

SEC. 633. (a) The Administrator shall establish, within the National Aeronautics and Space Administration, a research and development program consistent with the comprehensive 5-year program management plan under section 632 to ensure the development of a domestic hydrogen-fueled aircraft capability within the shortest time practicable.

(b) The Administrator shall initiate research or accelerate existing research in areas which may contribute to the development of a hydrogen-fueled aircraft capability.

(c) In conducting the program pursuant to this section, the Administrator shall encourage the establishment of domestic industrial capabilities to supply hydrogen-fueled aircraft systems or subsystems to the commercial marketplace.

(d) The Administrator shall, for the purpose of performing his responsibilities pursuant to this Act, solicit proposals for and evaluate any reasonable new or improved technology, a description of which could lead or contribute to the development of hydrogen-fueled aircraft technology.

(e) The Administrator shall conduct evaluations, arrange for tests and demonstrations and disseminate to developers information, data, and materials necessary to support efforts undertaken pursuant to this section.

FLIGHT DEMONSTRATION

SEC. 634. (a) Concurrent with the activities carried out pursuant to section 633, the Administrator shall, in consultation with the Secretary of Transportation, the Secretary of Energy, and the Hydrogen-Fueled Aircraft Advisory Committee established under section 637, prepare a comprehensive flight demonstration plan, the implementation of which shall provide confirmation of the technical feasibility, economic viability, and safety of liquid hydrogen as a fuel for

commercial transport aircraft. The comprehensive flight plan shall include—

(1) a description of the necessary research and development activities that must be completed before initiation of a flight demonstration program;

(2) the selection of a domestic site where demonstration activities can lead to early commercialization of the concept;

(3) an assessment of a preliminary flight demonstration to occur concurrently with the later states of research and development activities; and

(4) an implementation schedule with associated budget and program management resource requirements.

(b) The Administration shall transmit such comprehensive flight demonstration plan to the Congress within 2 years after the date of the enactment of this Act.

HYDROGEN PRODUCTION AND GROUND FACILITIES

SEC. 635. (a) The Administrator, in consultation with the Secretary of Transportation and the Secretary of Energy, shall define the systems, subsystems, or components associated with the production, transportation, storage, and handling of liquid hydrogen that are specifically required for and unique to the use of such fuel for commercial aircraft application.

(b) The Administrator shall structure the research and development program pursuant to section 633 to allow the development of the systems, subsystems, or components defined pursuant to subsection (a) of this section.

(c) The research and development program for hydrogen production, transportation, and storage systems, subsystems, and components which are suitable for inclusion as part of fully integrated hydrogen-fueled aircraft system, but which are not being specifically developed for such application shall be the responsibility of the Secretary of Energy. Such activities shall be included as part of the program established pursuant to title I of this Act, and shall be so conducted as to ensure compliance with hydrogen-fueled aircraft system constraints.

COORDINATION AND CONSULTATION

SEC. 636. (a) The Administrator shall have overall management responsibility for carrying out the program under this title. In carrying out such program, the Administrator, consistent with such overall management responsibility—

(1) shall utilize the expertise of the Departments of Transportation and Energy to the extent deemed appropriate by the Administrator, and

(2) may utilize the expertise of any other Federal agency in accordance with subsection (b) in carrying out any activities under this title, to the extent that the

Administrator determines that any such agency has capabilities which would allow such agency to contribute to the purpose of this title.

(b) The Administrator may, in accordance with subsection (a), obtain the assistance of any department, agency, or instrumentality of the executive branch of the Federal Government upon written request, on a reimbursable basis or otherwise and with the consent of such department, agency, or instrumentality. Each such request shall identify the assistance the Administrator deems necessary to carry out any duty under this title.

(c) The Administrator shall consult with the Secretary of Energy, the Administrator of the Environmental Protection Agency, the Secretary of Transportation, and the Hydrogen-Fueled Aircraft Advisory Committee established under section 207 in carrying out his authorities pursuant to this title.

ADVISORY COMMITTEE

SEC. 637. (a) There is hereby established a Hydrogen Fueled Aircraft Advisory Committee, which shall advise the Administrator on the program under this title.

(b) The committee shall be appointed by the Administrator and shall be composed of at least seven members from industrial, academic, financial, environmental, and legal organizations and such other entities as the Administrator deems appropriate. Appointments to the committee shall be made

within 90 days after the enactment of this Act. The committee shall have a chairman, who shall be elected by the members from among their number.

(c) the heads of the departments, agencies, and instrumentalities of the executive branch of the Federal Government shall cooperate with the committee in carrying out the requirements of this section and shall furnish to the committee such information as the committee deems necessary to carry out this section.

(d) The committee shall meet at least 4 times annually, notwithstanding subsections (e) and (f) of section 10 of Public Law 92–463.

(e) The committee shall review and make any necessary recommendations on the following items, among others—

(1) the implementation and conduct of the program under this title; and

(2) the economic, technological, and environmental consequences of developing a hydrogen-fueled aircraft capability.

(f) The committee shall prepare and submit annually to the Administrator a written report of its findings and recommendations with regard to the program under this title. The report shall include—

(1) a summary of the committee's activities for the preceding year;

(2) an assessment and evaluation of the status of the program; and

(3) comments on and recommendations for improvements in the comprehensive 5-year program management plan required under section 632.

(g) The Administrator shall provide such staff, funds, and other support as may be necessary to enable the committee to carry out the functions described in this section.

DEFINITIONS

SEC. 638. As used in this title—

(a) the term "Administrator" means the Administrator of the National Aeronautics and Space Administration;

(b) the term "capability" means proven technical ability; and

(c) the term "certifying agency" means any Government entity with direct responsibility for assuring public safety in the operation of the air transport system.

AUTHORIZATION OF APPROPRIATIONS

SEC. 639. AUTHORIZATIONS.—There is hereby authorized to be appropriated to carry out the purpose of this title—

(1) $10,000,000 for the fiscal year beginning October 1, 1991;

(2) $15,000,000 for the fiscal year beginning October 1, 1992;

(3) $20,000,000 for the fiscal year beginning October 1, 1993;

(4) $25,000,000 for the fiscal year beginning October 1, 1994; and

(5) $30,000,000 for the fiscal year beginning October 1, 1995.

TITLE VII—ADVANCED CIVILIAN REACTOR PROGRAMS

SEC. 701. FINDINGS AND PURPOSES.—Congress finds that—

(a) the use of energy generated from nuclear fission could potentially supplant economically the burning of fossil fuels and thereby contribute substantially to reducing the rate and scope of global climate change;

(b) the purpose of this title is to redirect programs in existence on the date of the enactment of this title for research, development, and demonstration of technologies for the generation of commercial electric power from nuclear fission. Notwithstanding any other provision of law, this title shall be the exclusive source of authority for appropriations for such programs; and

(c) for purposes of this section, programs for research, development, and demonstration of technologies for the generation of commercial electric power from nuclear fission include programs of the Secretary designated in appropriations acts for the fiscal year beginning on October 1, 1988, as Advanced Reactor Research and Development, Advanced Nuclear Systems, Facilities, and Program Direction.

SEC. 702. RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM.—(a) The Secretary shall carry out a comprehensive program of research and development of technologies for the generation of commercial electric power from nuclear fission that to the maximum extent practicable—

(1) permit modular design;

(2) exhibit passive safety;

(3) are adaptable to standardized construction and licensing;

(4) are cost-effective in comparison to alternative sources of electricity of comparable availability, reliability, and impact on the rate and scope of global climate change;

(5) minimize the volume of nuclear waste produced and the cost of nuclear waste disposal;

(6) prevent diversions of radioactive material for use in nuclear weapons; and

(7) minimize the cost of power plant decommissioning.

SEC. 703. APPROPRIATIONS.—(a) There is authorized to be appropriated to carry out the purposes of this title for the fiscal year beginning on October 1, 1991, not more than $100,000,000; for the fiscal year beginning October 1, 1992, not more than $200,000,000, and for the fiscal year beginning October 1, 1993, not more than $200,000,000.

SEC. 704. REPORTS.—The Secretary shall submit to the Congress by October 1, 1991, and every year thereafter, a comprehensive report on progress made toward the development of reactor designs which meet the criteria set out in section 702(a) of this Act. The report shall rank each design or technology in terms of its ability to meet these criteria, and shall show how the Secretary will focus his research efforts to most expeditiously achieve the development of a reactor design which meets these criteria. In addition, the report shall include the Secretary's recommendations for whatever steps he deems are needed to successfully achieve the purposes of this title.

TITLE VIII—FUSION

SEC. 801.—(a) Within 1 year after the date of the enactment of this section, the Secretary shall report to Congress on the status of research, development, and demonstration in technology for the production of electricity from both

magnetic and inertial confinement fusion, including international collaboration.

(b) The report under subsection (a) shall present a program of research, development, and demonstration of magnetic confinement and inertial confinement fusion for energy that would insure by 2010—

(1) a demonstration of the achievement of ignition conditions in both magnetic and inertial fusion test facilities;

(2) a demonstration of the technological feasibility of magnetic and inertial fusion as a source of electric power; and

(3) in the event that such feasibility is determined, the development of a design of a prototype commercial fusion reactor, accompanied by cost estimates and specifications sufficient to permit bids for construction of the reactor.

(c) The report shall include—

(i) an assessment of the actions needed and the funds that would be necessary to achieve the goals of the program under subsection (b);

(ii) an assessment of funds that would be provided by the United States under appropriate scenarios for international collaboration in a program

of fusion research, development, and demonstration that would achieve such goals;

(iii) a review and analysis of the major obstacles to international collaboration in such a program; and

(iv) the Secretary's recommendations for additional legal and budgetary authority required to implement the preferred scenario among those considered under paragraph (2).

TITLE IX—COAL

SEC. 901. REPORT.—(a) Within 9 months after the date of the enactment of this title the Secretary shall provide Congress with a comprehensive report reviewing the clean coal technologies to be developed in projects that have received Federal funds under the Department of Energy's Clean Coal Technology Program. This report shall analyze each such project to determine the change in the production of CO_2 that is likely to result from the project specifically and in total were the technology being developed widely implemented relative to alternative coal use technologies.

(b) Before submitting the report under subsection (a), the Secretary shall make a draft report available to the public and provide an opportunity for comment on such draft report. The Secretary shall provide appropriate responses to comments received in the final report.

(c) The Secretary shall include in the report his recommendations as to the most promising clean coal technologies that also would reduce the production of CO_2 per unit of energy delivered relative to alternative coal use technologies.

SEC. 902. PROGRAM.—(a) The Secretary shall establish and carry out a program of research, development and demonstration of techniques for recovery and disposal of CO_2 from automobiles, trucks, and buses, electric utility power operations, and industrial manufacturing processes.

(b) Within 6 months after the date of the enactment of this section the Secretary shall submit a report to Congress on his plans to implement subsection (a). Such report shall include the Secretary's recommendations of priority in research, development, and demonstration opportunities under this section. The report shall also include the Secretary's 5-year budget for the program under this section.

SEC. 903. COAL STUDY.—(a) The Secretary, through 1 or more of the Department's National Laboratories, shall establish and carry out a comprehensive program in the fundamental physics and chemistry of coal combustion. The program under this section shall examine the breakup of representative types of coal under combustion into final products at the molecular level.

(b) In designing the program under this section, the Secretary shall give priority to research that will clarify the fun-

damental mechanisms for the production of oxides of sulphur and nitrogen during the combustion process, with the ultimate goal of using information gained thereby to limit or control the introduction of these gases into the atmosphere.

(c) Within 6 months after the date of the enactment of this section the Secretary shall submit a report to Congress on his plans to implement subsection (a), including a 5-year budget for the program under this section.

SEC. 904. IMPROVED EFFICIENCY.—The Secretary shall support research that will improve the efficiency of coal generated electricity and industrial processes with priority given to those projects which have the greatest potential for reducing the generation of carbon dioxide.

SEC. 905. AUTHORIZATION.—There is authorized to be appropriated to the Secretary for purposes of this title not more than $5,000,000 for fiscal year 1991 and not more than $15,000,000 for fiscal year 1992, and not more than $25,000,000 for fiscal year 1993.

TITLE X—NATURAL GAS

SEC. 1001. NATURAL GAS FOR MASS TRANSIT PROGRAM.—(a) The Secretary shall, consistent with the Alternative Motor Fuels Act of 1988, Public Law 100-494, enter into cooperative agreements with, and provide financial assistance under this section to any municipal, county, or regional transit authority (hereinafter "authority") to demon-

strate the feasibility of using natural gas as a fuel for mass transit in urban areas.

(b) The program of the Secretary to implement the agreements under subsection (a) may include interested or affected private firms willing to provide assistance in cash or in kind for any such demonstration.

(c) The Secretary shall not enter into any agreement under subsection (a) with any municipal, county or regional transit authority unless such government body agrees to provide at least 25 percent of the costs of such demonstration.

(d) An authority may petition the Secretary for priority in allocating financial assistance under this section.

(e) The Secretary, at his discretion, may grant such priority under this section to any authority that demonstrates that the use of natural gas as a transportation fuel would have a significant effect on the ability of an air quality region to comply with applicable regulations governing air quality.

(f) Within 6 months after the date of the enactment of this section the Secretary shall report to Congress on his plans to implement this section.

(g) There is authorized to be appropriated to the Secretary not more than $30,000,000 for each of fiscal years 1991, 1992, and 1993 for purposes of this section.

SEC. 1002. REPORT.—Within 18 months after the date of the enactment of this title the Secretary, in consultation

with the Administrator of the Environmental Protection Agency and the President of the Gas Research Institute, shall submit to Congress a report on the feasibility of using natural gas in gasoline and diesel-powered vehicles to facilitate compliance by such vehicles with applicable emissions requirements for such vehicles.

SEC. 1003. NATURAL GAS USE IN FLEETS.—(a) The Secretary, consistent with the Alternative Motor Fuels Act of 1988, and after consultation with the president of the Gas Research Institute, shall establish and carry out a program, and provide financial assistance, to encourage the development and commercialization of natural gas use in passenger fleets, light duty trucks, and heavy duty trucks by providing for the purchase and construction of alternative fuel vehicles and associated refueling equipment.

(b) Both Federal and private fleets may be eligible for private assistance under this section. A public or private operator of a fleet may petition the Secretary for priority in allocating financial assistance under this section.

(c) The Secretary, at his discretion, may grant such priority to those fleets where the use of natural gas as a transportation fuel would have a significant effect on the ability of an air quality region to comply with applicable regulations governing air quality.

(d) To facilitate the use of natural gas fueled vehicles, the existing Federal vehicle anti-tampering regulations shall be amended by adding the following:

"The conversion of a vehicle from gasoline only to natural gas or natural gas and gasoline shall not be considered a violation of any anti-tampering provisions of the Federal law and implementing regulations provided that the conversion complies with emissions standards which shall be issued by the EPA administrator not later than October 31, 1989.".

(e) There is authorized to be appropriated to the Secretary not more than $30,000,000 for each of fiscal years 1991, 1992, and 1993, for purposes of this section.

SEC. 1004. TRAINING PROGRAM.—(a) The Secretary shall establish and carry out a training program for technicians who are responsible for vehicle installations of equipment that converts gasoline or diesel-fueled vehicles to the capability to run on natural gas alone, or on natural gas and either diesel or gasoline. Such training program shall provide these technicians with instruction on the correct installation procedures and techniques, adherence to specifications, vehicle operating procedures, and other appropriate mechanical concerns applicable to these vehicle conversions.

(b) The Secretary, at his discretion, shall enter into cooperative agreements with, and provide financial assistance, under this section, to appropriate parties to provide training

programs that will ensure the proper operation and performance of conversion equipment.

(c) There is authorized to be appropriated to the Secretary, consistent with the Alternative Motor Fuels Act of 1988, and after consultation with the president of the Gas Research Institute, not more than $5,000,000 for each of the fiscal years 1991, 1992, and 1993 for purposes of this section.

SEC. 1005. VEHICLE RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM.—(a) The Secretary, in consultation with the president of the Gas Research Institute, shall establish and carry out a program of research, development, and demonstration on techniques related to improving natural gas vehicle technology including, but not limited to, the following areas—

(1) gaseous fuel injection;

(2) carburetion;

(3) manifolding;

(4) combustion;

(5) power optimization;

(6) emissions control;

(7) novel gas compression concepts;

(8) advanced storage systems; and

(9) advanced gaseous fueling technologies.

(b) The Secretary, consistent with the Alternative Motor Fuels Act of 1988, after consultation with the president of the Gas Research Institute, shall enter into cooperative agreements with, and provide financial assistance, under this section, to the Gas Research Institute to perform the research and development to improve natural gas vehicle technology.

(c) There is authorized to be appropriated to the Secretary not more than $10,000,000 for each of the fiscal years 1991, 1992, and 1993 for purposes of this section.

SEC. 1006. NATURAL GAS RECOVERY, RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM.—(a) The Secretary, in consultation with the president of the Gas Research Institute, shall expand and continue a program of research, development, and demonstration on techniques to increase the availability of natural gas from—

(1) intensive recovery of natural gas in place in discovered reservoirs or formations; and

(2) more economic recovery of unconventional natural gas, including gas from tight sands, eastern shales gas from less permeable formations, coal-bed methane, and geopressured reservoirs.

(b) The Secretary shall seek to enter into joint research and development ventures with persons engaged in the production, transportation or major use of natural gas to imple-

ment the program under subsection (a). For purposes of this section a "joint research and development venture" means a joint research and development venture under the National Cooperative Research Act of 1984.

(c) There is authorized to be appropriated to the Secretary not more than $25,000,000 for each of the fiscal years 1991, 1992, and 1993 for purposes of this section.

SEC. 1007. ENGINE RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM.—(a) The Secretary, in consultation with the President of the Gas Research Institute, shall establish and carry out a program of research, development, and demonstration on high efficiency heat engines including, but not limited to, advanced gas turbine cycles for high efficiency electric power generation, such as—

(1) advanced combined cycle turbines;

(2) steam-injected gas turbines (STIG); and

(3) intercooled steam-injected gas turbines (ISTIG);

(b) The Secretary, after consultation with the president of the Gas Research Institute, shall enter into cooperative agreements with, and provide financial assistance, under this section, to appropriate parties, including, but not limited to the Gas Research Institute, to construct and demonstrate the high efficiency heat engines.

(c) There is authorized to be appropriated to the Secretary not more than $25,000,000 for each of the fiscal years 1991, 1992, and 1993 for purposes of this section.

SEC. 1008. The Secretary, after consultation with the president of the Gas Research Institute, shall establish priorities for research, development, and demonstration programs, and transmit a list of priorities to the Senate Committee on Energy and Natural Resources and the House Committee on Energy and Commerce for guidance in its use of research, development, and demonstration funds. The Secretary shall update the list every 2 years and submit the updated version to the aforementioned Congressional Committees.

TITLE XI—NATURAL RESOURCE POLICY

Subtitle A—General

SEC. 1101. ECOLOGICAL AND ENVIRONMENTAL RESOURCE STUDY.—(a) The Secretary of the Interior shall conduct a study of the ecological and environmental resources that would be affected by a global climate change. The study should include effects in wildlife habitat preservation, coastal protection, inland rivers and lakes, irrigation and reclamation, ground water protection, and national wildlife refuges and parks, national forests, and other Federal lands.

(b) The study should—

(1) include specific regional climatic and resource base information useful in anticipatory and mitigatory planning;

(2) identify actions that, if taken, could help mitigate the effects of global climate change; and

(3) evaluate the cost-effectiveness, including environmental externalities of possible action.

(c) The Secretary of the Interior shall consider the relative impact on global warming of all mineral leasing programs.

(d) The Secretary of the Interior and the Secretary of Agriculture shall consider the relative impact on global warming of all Federal forest land management programs, including timber sales and reforestation.

SEC. 1102. NATIONAL FORESTATION INITIATIVE.—The Secretary of Agriculture, in cooperation with the Secretary of Interior, shall report to the President and the Congress on the feasibility of a national forestation initiative. Such report shall include—

(a) an inventory of public, State, and private forested lands;

(b) an evaluation of the status of timber harvesting on those lands, including the extent to which those lands are being reforestated;

(c) an assessment of the extent to which Federal, State, and private lands can be reforested and afforested, including lands not necessarily suitable for timber harvesting such as urban areas;

(d) an evaluation of (1) the potential of a national forestation initiative reducing, mitigating, or preventing climate change, and (2) the measures needed to achieve that potential; and

(e) an assessment of the potential economic and environmental benefits and costs of such an initiative, the measures available to mitigate such costs, and an evaluation of the effectiveness of such measures.

SEC. 1103. URBAN FORESTRY AND ENERGY SAVINGS.—The Secretary of Energy, in consultation with the Secretary of Agriculture, and other relevant Government agencies, shall conduct a study of the potential for reducing carbon dioxide emissions by undertaking targeted urban tree plantings designed to reduce the air-conditioning needs of buildings. The study shall provide estimates of the cost-effectiveness of such a program and shall outline a range of Federal, State, and local public policies and incentives that would encourage public and private efforts to undertake such plantings.

The Secretary shall complete the study and submit it to the Congress within 18 months after the date of enactment of this Act.

Subtitle B—Tongass Timber Reform Act

TONGASS TIMBER REFORM ACT

SEC. 1103. DEFINITIONS.—As used in this title—

(a) The term "The Secretary" means the Secretary of Agriculture.

(b) Unless otherwise specified, any other term has the same meaning as used in the Alaska National Interest Lands Conservation Act as amended (Public Law 96–487), hereinafter referred to as ANILCA.

AMENDMENTS TO THE ALASKA NATIONAL INTEREST LANDS CONSERVATION ACT

SEC. 1104. ANNUAL APPROPRIATIONS FOR TIMBER MANAGEMENT AND RESOURCE CONSERVATION ON THE TONGASS NATIONAL FOREST.—Section 705(a) of ANILCA (16 U.S.C 539d(a)) is hereby repealed effective September 30, 1989, and subsections (b) and (c) of section 705 are redesignated as subsections (a) and (b), respectively.

SEC. 1105. IDENTIFICATION OF LANDS UNSUITABLE FOR TIMBER PRODUCTION.—Section 705(d) of ANILCA (916 U.S.C. 539d(d)) is hereby repealed.

REPORTS ON THE TONGASS NATIONAL FOREST

SEC. 1106. (a) MONITORING.—Section 706(a) of ANILCA (16 U.S.C. 539e(a)) is hereby repealed.

(b) STATUS.—Section 706(b) of ANILCA (16 U.S.C. 539e(b)) is amended as follows:

(1) Strike out "(b)" and insert in lieu thereof "(a)";

(2) Strike out "and (4)" and insert in lieu thereof "(4)";

(3) Strike out the period at the end of the section and insert in lieu thereof "; (5) the impact of timber harvest on subsistence resources, wildlife and fisheries resources, commercial fisheries, recreation resources and tourism; (6) effects of timber harvest on biological diversity; (7) effects of timber harvest on the old growth rain forest ecosystem, especially in areas of high volume, and measures to conserve the old growth ecosystem, especially in areas of high volume, and measures to conserve the old growth ecosystem; (8) timber supply and demand in southeastern Alaska; and (9) costs and revenues of the timber sale program.".

(c) CONSULTATION.—Section 706(c) of ANILCA (916 U.S.C. 539e(e)) is amended as follows:

(1) strike out "(c) and insert in lieu thereof "(b)".

(2) strike out "and the Alaska Land Use Council" and insert in lieu thereof "the southeast Alaska commercial fishing industry, and the Alaska Land Use Council".

SEC. 1107. TERMINATION OF LONG-TERM TIMBER SALE CONTRACTS IN ALASKA.—Title V of ANILCA is amended by adding at the end thereof the following new section:

"SEC. 508. TERMINATION OF LONG-TERM TIMBER SALE CONTRACTS IN ALASKA.

"Not later than 90 days after the date of enactment of this section, the Secretary shall terminate the long-term timber sale contracts numbered 12–11–010–1545 and A10fs–1042 between the United States and Alaska Pulp Corporation, and between the United States and Ketchikan Pulp Company, respectively."

MANAGEMENT OF THE TONGASS NATIONAL FOREST

SEC. 1108. (a) FINDINGS.—The Congress finds that—

(1) natural resources of the Tongass National Forest possess outstanding national characteristics of high value and benefit to the American people, and these resources are essential for subsistence activities and for the commercial fishing, recreation, and tourism industries which contribute significantly to the economy of southeast Alaska;

(2) the Tongass National Forest contains one of the last largely intact rain forests in the world's temperate latitudes, and must serve as an example of the type of protection, preservation and management that

will be required to stop the destruction of rain forest resources in other nations;

(3) current Forest Service management of the Tongass National Forest, in particular the amount of high volume old growth timber offered for sale and harvested, gives priority to timber harvest over other uses of the forest and thus is not consistent with the principle of multiple use or with requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974 and the National Forest Management Act of 1976, and cannot be sustained without jeopardizing natural resources that are of national significance and upon which the commercial fishing, recreation, and tourism industries and subsistence users of southeast Alaska depend;

(4) current Forest Service management practices are based on the Tongass National Forest Land Management Plan of 1979, as amended, which should be revised consistent with the provisions of this Act and with other laws applicable to the National Forest System, to significantly increase protection and enhancement of fish, wildlife, watershed, recreation, cultural, biological diversity, and old growth forest ecosystem resources, and to support the long-term best inter-

est of all natural resource dependent industries and subsistence communities in southeast Alaska.

(b) PURPOSE.—The purpose of this title is to require revision of the Tongass National Forest Land Management Plan of 1979, as amended, in conformance with this Act and other laws applicable to the National Forest System, to significantly increase protection of resources that are critical to the long-term best interests of the commercial fishing, recreation, and tourism industries, and the subsistence users in southeast Alaska, and which are of high value and benefit to the people of the United States. These include the fish, wildlife, watershed, recreation, cultural, biological diversity and old growth ecosystem resources and subsistence values of the Tongass National Forest.

SEC. 1109. DIRECTIVE AND REPORTS.—(a) In furtherance of the purpose of this title, the Secretary is hereby authorized and directed to fully revise the Tongass National Forest Land Management Plan of 1979, as amended, to conform with provisions of this Act and other laws applicable to the National Forest System. This revision shall replace any efforts to revise the Forest Plan that are predicated on sections of ANILCA that are repealed or amended by this Act.

(b) In revising the Forest Plan, the Secretary shall significantly increase the protection of fish, wildlife, watershed, recreation, cultural, biological diversity and old growth eco-

system resources and subsistence values of the Tongass National Forest. Planning and management of old growth resources shall give specific attention to areas of high volume old growth ecosystem as a whole.

(c) In revising the Forest Plan, the Secretary shall ensure that priority is given to the protection of fish, wildlife, watershed, recreation, cultural, biological diversity, and old growth ecosystem resources and subsistence values of the areas listed in section 302(b) of this Act.

(d) Within 30 days after this Act takes effect, the Secretary shall provide the Committee on Energy and Natural Resources of the Senate and the Committee on Interior and Insular Affairs of the House of Representatives with a report on the schedule for revision of the Tongass Land Management Plan, including the expected dates of publication of the draft and final plans.

(e) Within 1 year after this Act takes effect, and each year thereafter until the revised Tongass National Forest Land Management Plan is complete and ready for implementation, the Secretary shall provide the Senate Committee on Energy and Natural Resources and the Committee on Interior and Insular Affairs of the House of Representatives with a report describing the steps taken in furtherance of section 201(b) of this Act.

MORATORIUM ON TIMBER SALES AND HARVEST

SEC. 1100. (a) PURPOSE.—The purpose of this title is to impose a moratorium on the sale or commercial harvest of timber in certain areas having special values for fish and wildlife, subsistence, recreation, old growth, and other resources, pending revision of the Tongass National Forest Land Management Plan to conform with the new management directives provided in this Act.

(b) MORATORIUM.—Until such time as the Tongass National Forest Land Management Plan is completely revised and ready for implementation, there shall be no sale or harvest of timber, nor any associated development (including timber sale preparation or road construction) within any area specified in subsection (b) of this section. The moratorium shall apply to lands administered by the Forest Service, as generally depicted on appropriately referenced maps, as follows:

Area:	Approximate Acreage
Anan Creek	37,331
Berners Bay	35,379
Calder-Holbrook	62,335
Chichagof	353,540
Chuck River	125,574
Kadashan	33,641
Karta River	38,671
Kegan Lake	23,858
Naha River	31,926
Nutkwa	53,635
Outside Islands	95,524
Pleasant Island-Lemesurier Islands	15,527
Pt. Adolphus-Mud Bay	72,091
Port Houghton-Sanborn Canal	59,712
Rocky Pass	74,423
Sarkar Lakes	23,500

South Etolin Island	81,939
South Kuiu	190,301
Sullivan Island	3,985
Trap Bay	6,446
West Duncan Canal	118,812
Yakutat Forelands	232,962
Young Lake	18,173

Copies of maps depicting these areas shall be on file and available for public inspection in the offices of the Chief of the Forest Service in Washington, District of Columbia, and the Regional Forester in Juneau, Alaska.

TITLE XII—BASIC SCIENCE INITIATIVES

SEC. 1201. (a) PURPOSES.—The overall purpose of this title is to expand support for ongoing and new scientific research initiatives regarding the causes, mechanisms, and implications of the greenhouse effect and global climate change, on the part of the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS) ("the Agencies"), and the National Institute of Standards and Technology (NIST) for research on the development of safe, non-ozone depleting substitutes for chlorofluorocarbons (CFCs). The specific purposes of this title shall include—

(1) support for NASA, NSF, NOAA, and USGS in their research in such major climate-related processes as interactive atmospheric dynamics and chemistry; natural emissions of greenhouse gases; ocean-atmosphere-ice interactions; carbon cycle links to ocean and

terrestrial nutrients; cloud formation, dynamics, and radiative properties; precipitation processes; tropical global-ocean atmosphere interaction; global ocean circulation and heat capacity; sea-ice dynamics; global tropospheric chemistry; and stratospheric ozone chemistry; solar irradiance variations; paleoclimate; biosystem-climate interactions; and sea level-climate interactions; monitoring of river and coastal levels;

(2) support for the agencies in providing research to address scientific issues such as: detection of the greenhouse warming signal through land and ocean measurements of temperature and other climate-sensitive variables; research in past climate change; improvement of models to assess the rate and scope of climate change; understanding the role of clouds in reflecting solar radiation and in trapping terrestrial radiation; identifying sources and sinks of carbon dioxide and trace gases, especially methane; understanding the relationship between stratospheric ozone depletion and global climate change; the role of oceans in the global carbon cycle; modeling regional climate changes and hydrology; understanding the effects of climate change on ecosystems and climate biota feedbacks; understanding the role of changes in the polar ice packs on climate (e.g. reflection of solar radiation, influence on the

heat budget, and contribution to sea level rise); assessing the validity of climate models by testing them against the past climate record; and predicting the possible range of future climatic conditions that could arise from natural processes and selected scenarios of human perturbations;

(3) support for the completion or continuation of the Agencies' space missions and experiments to study the composition and dynamics of the atmosphere; measure the Earth's energy balance; observe ocean and ice surfaces; collect data on the Earth's radiation budget; measure sea surface temperature and monitor ocean biological activity and land vegetation; measure volcanic activity; and

(4) support for the National Institute of Standards and Technology's efforts to find alternative refrigerants or other technologies that meet stringent requirements with respect to health, stability, thermophysical properties, and cost, and do not result in decreased energy efficiency; develop effective replacements for harmful CFCs in time to be of value to CFC dependent industries in meeting their product line changes for the Montreal Protocol schedule; develop models to correlate and extend the available measured property data;

and assist industry in evaluating the full potential of alternative fluids.

(b) There is hereby authorized to be appropriated $275,000,000 in additional funding to the following agencies over the fiscal years 1991, 1992, and 1993, to support each agency's efforts in carrying out the purposes of this title:

(1) $100,000,000 to NASA;

(2) $60,000,000 to NOAA;

(3) $75,000,000 to NSF;

(4) $30,000,000 to USGS; and

(5) $10,000,000 to NIST.

TITLE XIII—DEVELOPMENT ASSISTANCE

SEC. 1301. BILATERAL TROPICAL FORESTRY PROGRAM.—(a) Not later than 1 year after the enactment of this title, the Secretary of State, in conjunction with the Secretary of the Treasury, Administrator of the Agency for International Development, the Secretary of Interior, and the Secretary of Agriculture shall transmit to Congress a report containing—

(1) a description and inventory of the existing forest resources in all tropical countries of the world;

(2) an evaluation of the potential in each tropical nation for reforestation, afforestation, and conservation of existing forest resources;

(3) a description of appropriate mechanisms in each country for preserving forest resources and creating new forested area, including, but not limited to, choice of mixed species to encourage a diverse forest and discourage monoculture estates, and involvement of local groups in the design, implementation, and monitoring of projects; and

(4) the potential for reducing, mitigating, or preventing climate disruption by providing bilateral development assistance and other forms of assistance and incentives to tropical countries for reforestation, afforestation, and conservation of existing forest resources.

The report referred to in this subsection shall be prepared in consultation with the government and the public in each tropical country and shall be updated and transmitted to Congress every 3 years.

(b) Within 1 year after the completion of the report required under subsection (a) and every 3 years thereafter, the same agencies, in consultation with the government and public in each tropical country and interested members of the public in the United States, shall establish and transmit to Congress a forest plan with goals for each tropical country. These goals shall include maximum feasible conservation of existing forest areas and reforestation and afforestation in areas not covered by forests.

(c) The Administrator of the Agency for International Development shall make development assistance moneys, export credits, and other forms of financial support available for projects and programs to implement the plan required by subsection (b). The Administrator shall ensure that all activities supported by the United States bilateral foreign assistance are consistent with the plan. Beginning 2 years after the approval of the first plan, the Administrator, in allocating development assistance moneys to countries identified in the plan, shall take account of the success or lack of success of each country in meeting the goals established in the plan.

(d) The Administrator shall promote support by other bilateral donors for activities necessary to implement the plan.

(e) Not later than 1 year after the date of enactment of this title, and annually thereafter, the Department of State, in cooperation with the Department of Interior, and the Department of the Treasury, the Department of Agriculture, and the Agency for International Development shall submit to Congress a report describing actions taken pursuant to this section, the extent to which other donors have supported actions necessary to implement the forest plan, the extent to which each tropical country has succeeded in achieving the goals set out in the plan, and how the success or lack of success of each country in meeting the goals established in

the plan have been taken into account in allocating development assistance moneys to each country.

SEC. 1302. MULTILATERAL TROPICAL FORESTRY PROGRAM.—(a) The Secretary of the Treasury shall instruct the United States' Executive Director of the multilateral development banks to promote the adoption by each such bank of a forestry program substantially equivalent to the program set out in section 1301 and containing the following components:

(1) identification of each borrowing country's potential for afforestation;

(2) establishment of goals for afforestation for each borrowing country, in consultation with the government and the public in that country;

(3) creation of incentives to encourage afforestation and disincentives to discourage deforestation; and

(4) allocation of the resources of each such bank to each borrowing country in proportion to the degree with which such country has created new forested areas and protected existing forested areas.

(b) Beginning 2 years after the enactment of this title, the Secretary of the Treasury shall instruct the United States' Executive Director to each of the multilateral development banks to oppose loans and other financial or technical assistance to any borrowing country that has not successfully

established and successfully implemented a program setting reasonable goals for that country for preserving existing forest resources and creating new forested areas, except where the Secretary determines that such goals are advanced more effectively by actions other than voting against such assistance.

The Secretary of State shall instruct the United States representative to the United Nations Food and Agriculture Program to promote the establishment and coordinate the implementation of forestry plans for tropical countries substantially equivalent to those set out in section 1301 and subsection (a) of this section that contains incentives to encourage afforestation and disincentives to discourage deforestation.

(d) The Secretary of State shall instruct the United States Ambassador to the United Nations Development Program to adopt and implement forestry programs for recipient countries substantially equivalent to those set out in section 1301 and subsection (a) of this section that contain incentives to encourage afforestation and disincentives to encourage deforestation. Beginning two years after the enactment of this title, the Secretary of State shall instruct the United States Ambassador to the United Nations to oppose the adoption of any country programs for any recipient country that has not established and successfully implemented a program setting reasonable goals for that country for preserving existing

forest resources and creating new forested areas, except where the Secretary determines that such goals are advanced more effectively by actions other than opposing the adoption of such a plan.

(e) The Secretary of State shall instruct the United States representative to the International Tropical Timber Organization to promote:

(1) a major emphasis by the organization on conservation activities and financing of forest conservation projects; and

(2) the adoption of codes of conduct for commercial logging and private sector timber operations.

(f) Not later than 1 year after the date of enactment of this title, and annually thereafter, the Secretary of the Treasury and the Secretary of State shall submit to Congress a report describing progress by each of the multilateral development banks, the United Nations Food and Agriculture Program, the United Nations Development Program, and the International Tropical Timber Organization in adopting and implementing programs meeting the standards set out in this section, including in particular:

(1) efforts by the Department of the Treasury, the Department of State, and other Federal agencies to assure implementation of multilateral development programs substantially equivalent to that set forth in sec-

tion 1302 and subsection (a) of this section, and the result of such efforts;

(2) progress by the United Nations Food and Agriculture Organization in promoting the establishment and coordinating the implementation of forestry plans for tropical countries meeting the criteria set forth in section 1301 and subsection (a) of this section;

(3) progress in the identification of each multilateral development bank, the United Nations Food and Agriculture Program, the United Nations Development Program of the potential for afforestation by recipient countries;

(4) progress in the establishment of goals by each multilateral development bank, the United States Food and Agriculture Program, and the United States Development Program for afforestation by each recipient country;

(5) the nature of incentives and disincentives created by each multilateral development bank and the United Nations Development Program to encourage afforestation and to discourage deforestation, respectively;

(6) the extent to which the allocation of the resources of each multilateral development bank and the United Nations Development Program to recipient

countries is proportional to the success or lack of success of such country in creating new forest areas and protecting existing forest areas; and

(7) a description of proposed loans, country programs, and other financial and technical assistance to which subsections (b) and (d) apply, and votes and other actions on proposal by United States Executive Director to the relevant multilateral development bank and the United States Ambassador to the United Nations.

SEC. 1303. TRADE IN WOOD AND WOOD PRODUCTS.—(a) Not later than 1 year after the enactment of this title, the Secretary of Commerce, in consultation with interested members of the public, shall promulgate regulations requiring wood and products containing wood imported into the United States to bear a label containing the following information:

(1) the country or countries in which wood or woods were harvested; and

(2) the scientific and common names of such wood or woods.

(b) Not later than 4 years after the enactment of this title, the Secretary of Commerce, in consultation with the Secretary of State, the Administrator of the Agency for International Development, the Secretary of the Treasury,

and interested members of the public, shall by regulation prohibit the importation into the United States of wood and products containing wood from—

(1) those tropical countries that have not successfully achieved the goals established under sections 1301 and 1302 of this title;

(2) those countries that import wood or products containing wood harvested in the countries identified in paragraph (1); and

(3) those countries that permit transit of wood or products containing wood harvested in those countries identified in paragraph (1).

(c) Not later than 2 years after the publication of the regulation referred to in subsection (a) and no less frequently than biennially thereafter, the Secretary of Commerce, in consultation with the Administrator of the Agency for International Development, the Secretary of the Treasury, and interested members of the public, shall review and, as necessary, revise the regulation referred to in subsection (a).

(d) The President shall encourage those countries which import or consume wood or wood products from countries identified in sections 1301 and 1302 to adopt laws and regulations substantially equivalent to the regulation referred to in subsection (a).

(e) The Secretary of Commerce, not later than 1 year after the initial publication of the regulation referred to in subsection (a) and annually thereafter, shall submit a report to the Congress describing—

(1) progress in controlling imports into the United States of wood and wood products from countries that have not successfully achieved the goals established under sections 1301 and 1302; and

(2) progress by those countries which import or consume wood or wood products from countries identified in paragraph (1) in controlling imports of such wood and wood products.

SEC. 1304. BILATERAL ENERGY PROGRAM.—Section 106 of the Foreign Assistance Act of 1961 (22 U.S.C. 2151d) is amended by—

(a) changing the title of the section to read: "Sustainable Energy Development, Private Voluntary Organizations, and Selected Development Activities.";

(b) striking out all subsection (a)(1) except the first 2 sentences and striking out all of subsection (a)(2);

(c) inserting the following new subsection (a)(2):

"(2) The Congress finds that energy conservation, improvements in end use energy efficiency, and energy production from renewable, decentralized sources have great potential for meeting energy needs in developing nations, especial-

ly the needs of the rural poor. These techniques can enable developing countries to make efficient use of scarce resources; minimize environmental harm (including warming of the earth's atmosphere due to the "greenhouse effect"); lessen the danger of nuclear weapons proliferation; and reduce dependence on dwindling oil reserves and expensive imported energy. Often, energy needs can be met more cheaply and more employment can be generated by these methods than by production of energy from conventional sources.".

(d) striking out the last sentence of subsection (b)(2), redesignating that subsection as subsection (a)(3), and inserting at the end of that subsection the following:

"Such programs also may include any type of assistance aimed at energy efficiency, improvements in end use energy efficiency, and assistance for transmission facilities to increase the availability of energy in rural areas. No assistance shall be furnished under this Act for large-scale production of energy from fossil fuels.".

(e) inserting the following new subsection (a)(4):

"(4) In providing assistance to developing countries as authorized in subsection (3), the President shall—

"(A) prepare for each aid-receiving country, in cooperation with the government and the public in each

country and interested members of the public in the United States, an analysis—

"(i) describing feasible actions that can reduce emissions of 'greenhouse gases', while at the same time meeting development needs, through actions which improve end use energy efficiency, promote reliance on renewable energy sources, or encourage energy efficiency or use of alternative fuels;

"(ii) comparing the economic and environmental costs of the actions described in subparagraph (i) with the economic and environmental costs of the actions described in subparagraph (i) with the economic and environmental costs of investments to provide additional supplies of energy; and

"(iii) analyzing the need for foreign assistance, and especially United States bilateral assistance, to make possible the actions described in subparagraph (i).

"(B) provide technical assistance and support projects to improve energy efficiency, with emphasis on training, information and institution-building in all sectors; improvement of indigenous capabilities to develop and implement least cost planning strategies and pro-

grams of energy efficiency; developing indigenous capabilities to adapt technologies of energy conservation and end use energy efficiency; and, in transportation, energy-saving methods of mass transit (such as light rail, buses, and van pools), energy-efficient motor vehicles and railroads, traffic management techniques (such as computerization of traffic signals and fuel savings at airports), and transfer of appropriate United States technologies;

"(C) support projects to develop and demonstrate energy conservation, improvements in end use energy efficiency, and small-scale, decentralized, renewable energy sources for rural areas. Such projects shall use appropriate technologies and methods suited to the local environment, shall feature close consultation with and involvement of local people at all stages of project design and implementation, and shall be directed toward the earliest possible widespread application. Appropriate technologies include but are not limited to biomass, biogas, wind energy, passive solar, solar electricity, fuel cells, and low-head hydroelectric generation;

"(D) whenever appropriate, accomplish the objectives of this subsection through projects managed by

private and voluntary organizations or international or regional or national nongovernmental organizations;

"(E) direct the Administrator of the Agency for International Development, in consultation with the President of the Export-Import Bank and the President of the Overseas Private Investment Corporation, to encourage private sector investment in energy efficient technologies in developing countries;

"(F) make the analyses referred to in subsection (A) available to the public and transmit them to the Congress at least annually;

"(G) beginning one year after the enactment of this title, refuse to approve any project or program authorized by this subsection involving the obligation of more than $100,000 unless such an analysis has been prepared, transmitted to the Congress, and made available to the public;

"(H) promote vigorously the adoption by other bilateral donors of energy efficient programs for countries that receive development assistance that emphasize least-cost energy planning, energy conservation, and end use energy efficiency; and

"(I) not later than 1 year after the date of enactment of this title, and annually thereafter, submit to the Congress a report describing progress under the

program established by this section, including in particular, the nature of all projects supported; their costs and results; progress in reducing emissions of greenhouse gases; and progress by other bilateral donors in implementing programs of least cost energy planning, energy conservation, and end use energy efficiency for aid-receiving countries.".

(f) striking out subsection (b), redesignating subsection (c) as subsection (a)(5), and redesignating subsections (d) and (e) as subsections (b) and (c), respectively.

SEC. 1305. MULTILATERAL ENERGY CONSERVATION AND EFFICIENCY PROGRAM.—(a) The Secretary of the Treasury shall instruct the United States Executive Director to each of the multilateral development banks vigorously to promote the adoption by each such bank of an energy conservation and efficiency and containing the following components:

(1) least cost energy planning for each borrowing country that—

(A) gives priority to projects and programs to support energy conservation, end use energy efficiency, and renewable energy sources in major economic sectors; and

(B) compares the economic and environmental costs of the actions described in subparagraphs (A) with the economic and environmental costs of investments to provide additional supplies of energy;

(2) analysis for each proposed loan to support additional power generating capacity comparing the economic and environmental costs of investments in reduction of demand for energy, including energy conservation and end use energy efficiency, with the economic and environmental costs of the proposal;

(3) an implementation strategy, including technical assistance grants as appropriate, for implementing the plan referred to in paragraph (1);

(4) strict standards requiring consistency of each proposed loan with the relevant least cost energy plan for each borrowing country; and

(5) measures to encourage reform of macroeconomic policies, such as energy prices, to facilitate energy conservation and end use energy efficiency.

(b) Beginning 2 years after the enactment of this title, the Secretary of the Treasury shall instruct the United States Executive Director to each of the multilateral development banks to oppose loans and other financial or technical assistance to any borrowing country for which a least cost energy

plan giving priority to energy conservation, end use energy efficiency, and renewable energy sources is not in place, except where the Secretary determines that such goals are advanced more effectively by actions other than voting against such assistance.

(c) The Secretary of State shall instruct the United States Ambassador to the United Nations vigorously to encourage the United Nations Development Program to adopt and implement energy conservation and efficiency programs for recipient countries substantially equivalent to those set out in subsection (a) that require least cost energy planning to give priority to energy conservation, end use energy efficiency, and renewable energy sources. Beginning 2 years after the enactment of this title, the Secretary of State shall instruct the United States Ambassador to the United Nations to oppose the adoption of any country programs for any country for which a program of least cost energy planning giving priority to energy conservation, end use energy efficiency, and renewable energy sources is not in place, except where the Secretary determines that such goals are advanced more effectively by actions other than opposing the adoption of such plan.

(d) Not later than 1 year after the date of enactment of this title, and annually thereafter, the Secretary of the Treasury and the Secretary of State shall submit to the Congress a

report describing progress by each of the multilateral development banks and the United Nations Development Program in adopting and implementing programs meeting the standards set out in subsections (a) and (c), including in particular—

(1) efforts by the Department of the Treasury, the Department of State, and other Federal agencies to assure implementation by each of the multilateral development banks and the United Nations Development Program of programs substantially equivalent to those set out in this section, and the results of such efforts;

(2) progress by each multilateral development bank and the United Nations Development Program in drafting and adopting least cost energy plans for each recipient country;

(3) the absolute dollar amounts, and proportion of total lending in the energy sector, of loans, portions of loans, or projects approved by each multilateral development bank and the United Nations Development Program in the previous year for projects or programs of energy conservation and end use energy efficiency; and

(4) a description of proposed loans, country programs, and other financial and technical assistance to which subsections (b) and (c) apply, and votes and

other actions on proposals by the United States Executive Director to the relevant multilateral development bank and the United States Ambassador to the United Nations.

SEC. 1306. ENVIRONMENTAL CONSERVATION AND DEBT REDUCTION.—(a) It is the policy of the United States that the Secretary of the Treasury, in consultation with interested members of the public including commercial banks, shall enter into negotiations with selected developing country governments to obtain improvements in policies in the foresty and energy sectors by those countries as a condition of reducing or converting sovereign and private debt owned to creditors in the United States. As a condition of the adoption of policies or programs to preserve existing forested areas, encourage the creation of new forested areas, or promote energy conservation or end use energy efficiency, the Secretary may reduce the principal of, extend payments on, or reduce the rate of interest on up to one-half of the total sovereign debt owed to the United States by developing country governments.

(b) Not later than 1 year after the enactment of this title, the Secretary of the Treasury, in consultation with interested members of the public including commercial banks, shall promulgate regulations to implement the program established in subsection (a). Such regulations shall—

(1) identify those developing countries that are promising candidates for participation in such a program from the point of view of their contribution to global climate disruption and the total amount of debt owed to official and private creditors in the United States;

(2) establish a timetable of the initiation of negotiations with each such country; and

(3) establish criteria and standards for the adoption, implementation, and monitoring or programs and policies in the forest and energy sectors by developing country governments that wish to participate in the program established by subsection (a).

(c) The Secretary of the Treasury, in consultation with interested members of the public including commercial banks, shall encouarge the adoption of joint initiatives of debt reduction and conversion by the public and private sectors in other member countries of the Organization for Economic Cooperation and Development. (a) Not later than 1 year after the enactment of this title, the Administrator of the Agency for International Development shall transmit to the Congress a report for each country that receives development assistance monies from the United States containing—

(1) a least cost energy plan that provides for economic development;

(2) a comparison of the economic and environmental costs of alternative investments in the energy sector, such as conservation and end use efficiency, with the economic and environmental costs of investments to provide additional power generating capacity;

(3) an implementation strategy, including technical assistance grants as appropriate, for implementing the plan referred to in paragraph (1); and

(4) the potential for reducing, mitigating, or preventing the climate disruption by providing bilateral development assistance for least cost energy planning, energy efficiency, and end use efficiency.

(b) The report referred to in subsection (a) shall be updated and transmitted to the Congress every 2 years. The first report and all subsequent reports shall be prepared in consultation with the government and the public in each recipient country and interested members of the public in the United States. The Administrator shall assure that all development assistance moneys expended in each recipient country are consistent with the least cost plan applicable to that country;

(c) The Administrator shall promote the adoption by other bilateral donors of energy efficiency programs for countries that receive development assistance that emphasize

least cost energy planning, energy efficiency, and end use efficiency;

(d) Not later than 1 year after the date of enactment of this title, and annually thereafter, the Administrator shall submit to the Congress a report describing progress under the program established by this section, including in particular—

(1) the nature of energy projects supported in each recipient country and the dollar amount of each;

(2) improvements in energy conservation and end use efficiency resulting from projects financed in each recipient country;

(3) progress in reducing, mitigating, or preventing climate disruption by providing bilateral development assistance to recipient countries through support of projects to encourage energy conservation and end use efficiency; and

(4) progress by other bilateral donors in implementing least cost energy programs for recipient countries.

SEC. 1307. MULTILATERAL ENERGY EFFICIENCY PROGRAM.—(a) The Secretary of the Treasury shall instruct the United States Executive Director to each of the multilateral development banks to promote the adoption by each such bank of an energy efficiency program substantially equivalent

to the program set out in section 1304 and containing the following components:

(1) least cost energy planning for each borrowing country;

(2) analysis for each proposed loan to support additional power generating capacity comparing the economic and environmental costs of alternative investments in the energy sector, including energy conservation and end use efficiency, with the economic and environmental costs of the proposal;

(3) an implementation strategy, including technical assistance grants as appropriate, for implementing the plan referred to in paragraph (1); and

(4) strict standards requiring consistency of each proposed loan with the relevant least cost energy plan for each borrowing country.

(b) The Secretary of the Treasury shall instruct the United States Executive Director to each of the multilateral development banks to notify the staff of each bank that all future contributions to such bank from the United States shall be conditioned upon adoption and successful implementation of a program meeting the standards set out in subsection (a).

(c) Not later than 1 year after the date of enactment of this title, and annually thereafter, the Secretary of the Treasury shall submit to the Congress a report describing progress

by each of the multilateral development banks in adopting and implementing programs meeting the standards set out in subsection (a), including in particular—

(1) efforts by the Department of the Treasury and other executive branch agencies to assure implementation by each of the multilateral development banks of a program substantially equivalent to that set out in this section, and the results of such efforts;

(2) progress by each multilateral development bank in drafting and adopting least cost energy plans for each borrowing country; and

(3) the absolute dollar amounts, and proportion as total lending in the energy sector, of loans or portions of loans approved by each multilateral development bank in the previous year for products or programs of energy efficiency and end use efficiency.

SEC. 1308. REPORT BY THE ADMINISTRATOR OF THE AGENCY FOR INTERNATIONAL DEVELOPMENT.—Not later than 1 year after the enactment of this title, the Administrator of the Agency for International Development, in consultation with the Secretary of the Treasury and the Secretary of State, shall submit to the Congress a report describing options and strategies for the use of bilateral and multilateral development assistance programs sponsored by the United States to control emissions into the atmosphere of carbon di-

oxide, nitrous oxide, methane, and other greenhouse gases. Interalia, this report shall analyze mechanisms by which strategies to encourage afforestation, reforestation, energy conservation, end use energy efficiency, and renewable energy sources can be incorporated into the programs of the International Monetary Fund.

TITLE XIV—INTERNATIONAL ACTIVITIES

Subtitle A

SEC. 1401. MULTILATERAL GLOBAL CLIMATE PROTECTION CONVENTION. (a) It is the policy of the United States that the Secretary of State, in consultation with the Administrator of the Environmental Protection Agency and the Secretary of Energy, and science agencies (e.g., NASA, NOAA, and NSF) shall convene an international meeting to be held in the United States with invitations to representatives of all countries of the world, the purpose of which shall be to actively encourage the adoption of a binding multilateral global climate protection convention containing measures at least as stringent as those in this Act.

(b) The Secretary of State shall sponsor such other meetings as may be necessary to assure that the convention is opened for signature no later than the end of 1992.

(c) The Secretary of State shall seek to assure that the convention, through least cost energy planning, energy efficiency, and end use efficiency, requires a reduction of not less

than 20 percent in global generation of carbon dioxide over 1988 levels by the year 2000, a reduction not less than 50 percent in global generation of carbon dioxide over 1988 levels by the year 2015, and appropriate reductions in emissions of nitrous oxide, methane and other greenhouse gases.

SEC. 1402. MULTILATERAL AGREEMENT TO REDUCE EMISSIONS OF OXIDES OF NITROGEN.—Not later than 1 year after the enactment of this title, the Secretary of State, in consultation with the Administrator of the Environmental Protection Agency, the Secretary of Energy, and the administrators of NIST, NOAA, and NASA shall initiate negotiations on behalf of the United States and actively encourage the adoption by the end of 1991 of a binding multilateral agreement requiring reductions of not less than 30 percent in emissions of oxides of nitrogen over 1987 levels by the year 1998.

SEC. 1403. REASSESSMENT OF MONTREAL PROTOCOL ON SUBSTANCES THAT DEPLETE THE OZONE LAYER.—(a) Not later than 1 year after the enactment of this title, the Secretary of State, in consultation with the Administrator of the Environmental Protection Agency, shall request and, if necessary, convene in the United States such meetings of the parties to the Montreal Protocol on Substances that Deplete the Ozone Layer as may be necessary for the reassessment of the control measures contained therein.

(b) The Secretary of State shall actively encourage the adoption of additional control measures requiring the virtual elimination of emissions of all substances identified in the Montreal Protocol within 5 to 7 years from the date of enactment of this title and appropriate control measures for other ozone-depleting chemicals not identified in the Montreal Protocol.

SEC. 1404. INTERNATIONAL NUCLEAR CONFERENCE.—The Secretary of State, in consultation with the Secretary of Energy, shall convene an international meeting to be held in the United States with invitations to representatives of all countries of the world, the purpose of which shall be to encourage the exchange of information concerning passively safe nuclear reactors, nuclear safety, and disposal of nuclear waste.

SEC. 1405. SPECIAL PROGRAMS.—The Secretary of State should encourage the establishment of a special office of the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to monitor annual generation of CO_2 and estimated trace gases on a country-by-country basis. That office shall also be responsible for assisting global negations and ultimately administering a global protocol.

SEC. 1406. (a) It is the policy of the United States that sustainable economic growth must be predicated on sustain-

(2) increase funds available for applied research and development of new contraceptive technologies with a particular focus on methods adaptable for use in developing countries.

(c) There is hereby authorized to be appropriated to the President $500,000,000 for fiscal year 1991 and $540,000,000 for fiscal year 1992 and $580,000,000 for fiscal year 1993 for international population and family planning assistance. Of the funds appropriated, not less than 16 percent or $60,000,000, whichever amount is less, shall be solely available for the United Nations Population Fund. None of the funds made available for international population and family planning assistance may be used to pay for the performance of involuntary sterilization or abortion or to coerce any person to accept family planning services. Restrictions may be applied by the President to information, counseling, or services that may be provided by family planning entities abroad only to the extent that the same restrictions are applied by the President to information, counseling, and services that may be provided by family planning entities receiving funds under grants and contracts made under title X of the Public Health Service Act (42 U.S.C. 300 and following).

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