

CO₂ GREENHOUSE AND CLIMATE ISSUES

HENRY SHAW

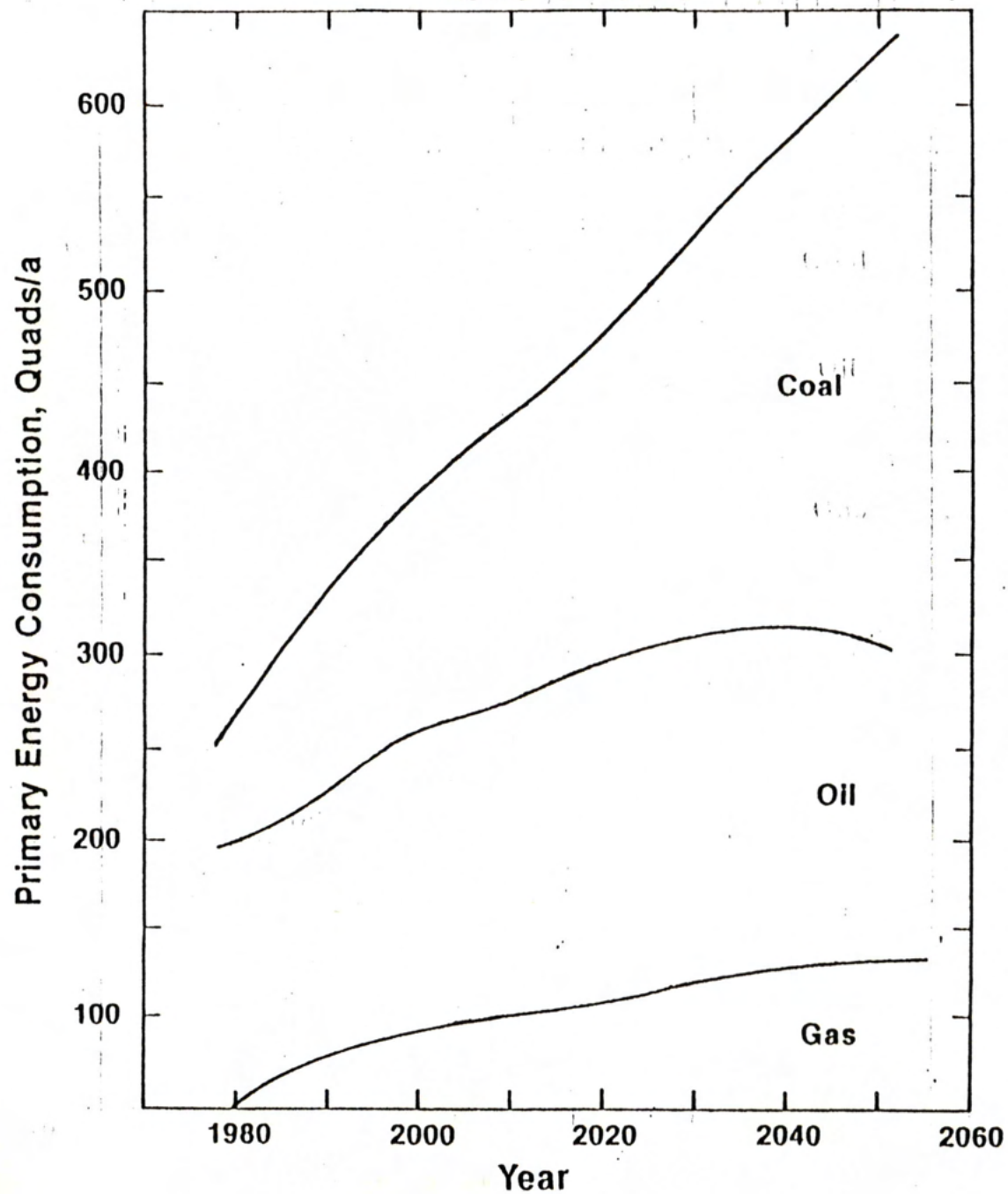
PRESENTED AT

EUSA/ER&E ENVIRONMENTAL CONFERENCE

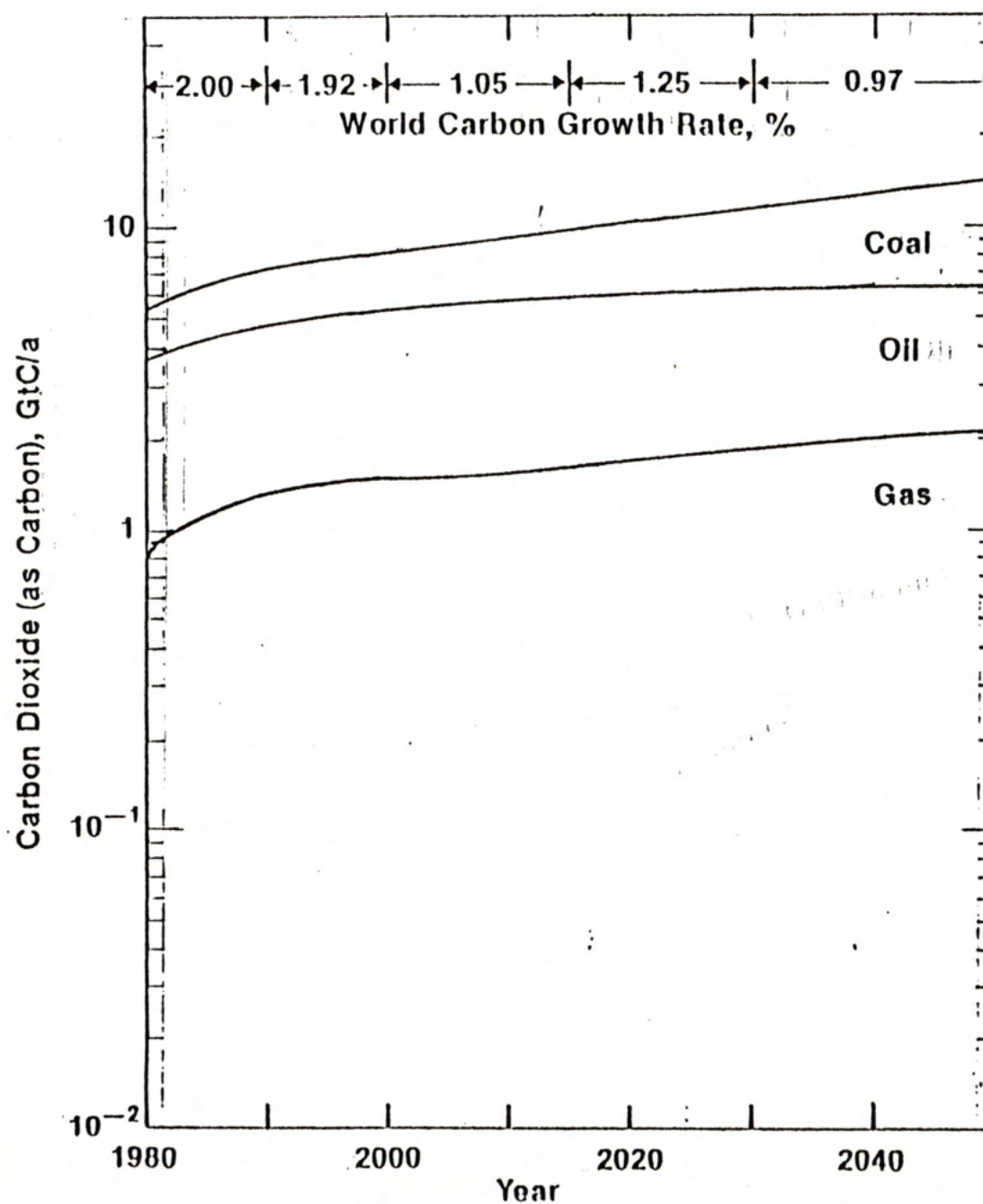
FLORHAM PARK, NEW JERSEY

MARCH 28, 1984

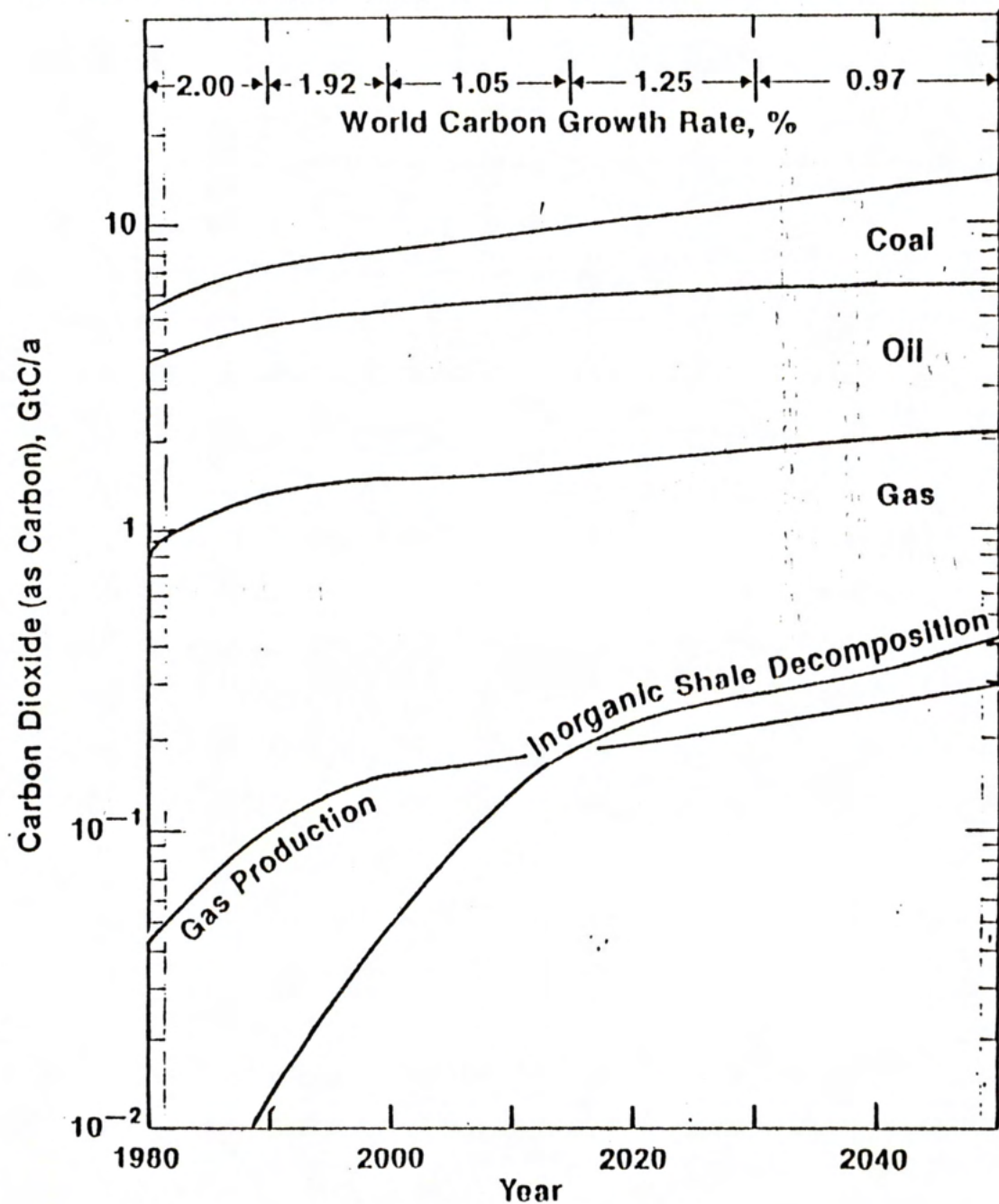
PRIMARY FOSSIL FUEL ENERGY CONSUMPTION 2030 STUDY



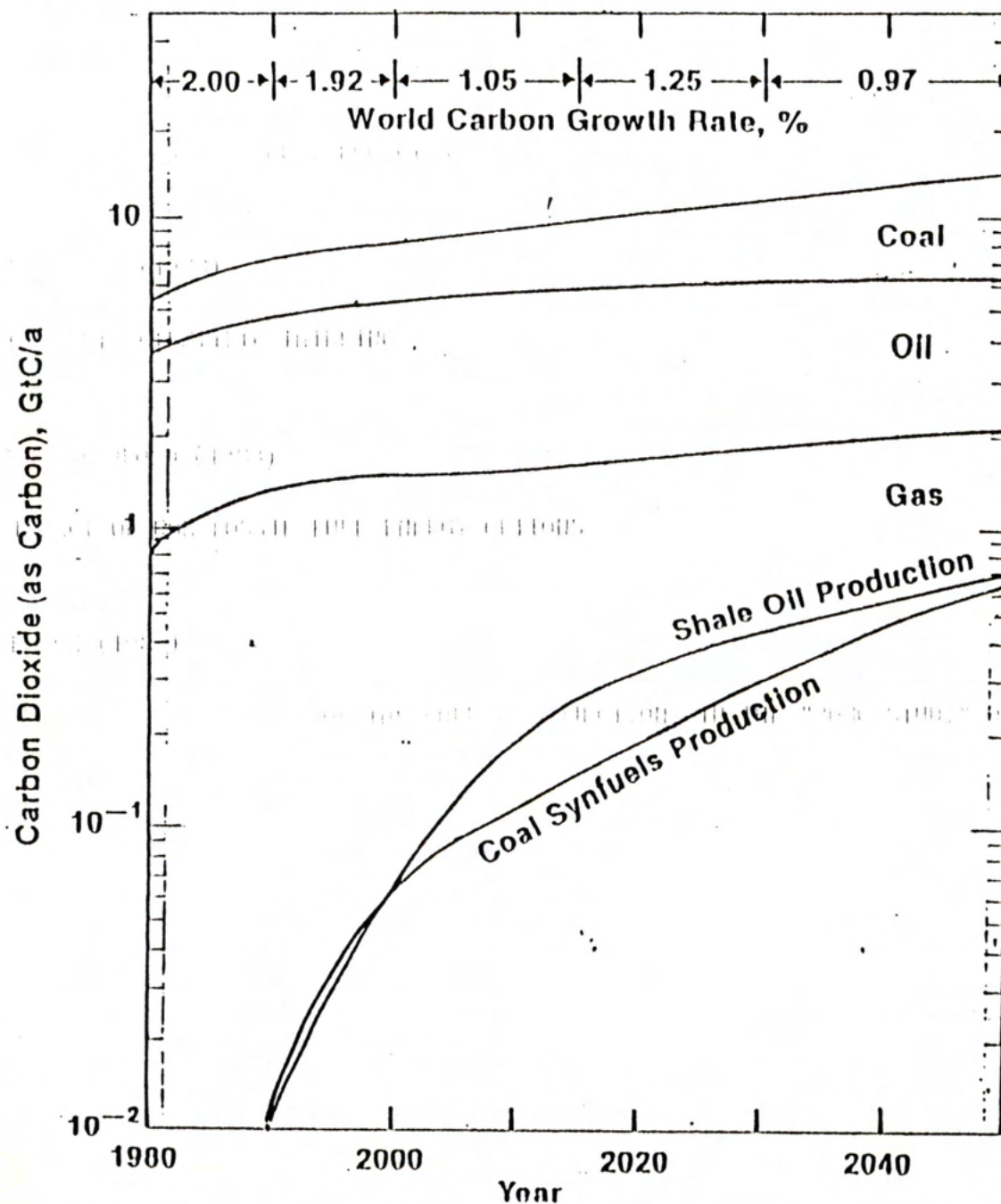
PROJECTED CARBON DIOXIDE (AS CARBON) FROM WORLD PRIMARY FOSSIL FUEL CONSUMPTION



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RESULTS/EFFECTS

	<u>EPA</u>	<u>NRC/NAS</u>	<u>MIT</u>	<u>EXXON</u>
• TIME FOR CO ₂ DOUBLING	2060	2075	-	2090
• AVERAGE TEMPERATURE RISE	3 ⁰ C	~ 2 ⁰ C	1.5-4.5 ⁰ C	1.3 - 3.1 ⁰ C
• OTHER GASES IMPACT	-1.6 to 3.3 ⁰ C	~1 ⁰ C	-	-
• SEA LEVEL RISE	150 cm, 2040 215 cm, 2100	70 cm 2080 (3-4 ⁰ C rise)	-	-
• PRECIPITATION	POSSIBLE MAJOR CHANGES	DRIER MIDWEST	SIGNIFICANT, BUT UNPREDICTABLE	-
• AGRICULTURAL	PLUSES & MINUSES	BENEFITS WILL BALANCE DEBITS	SIGNIFICANT, BUT UNPREDICTABLE	-
• AIRBORNE CO ₂ FRACTION	0.6 to 0.8	0.4 - 0.6	0.4 to 0.6	0.53
• IMPACT OF ALTERNATE ENERGY SOURCES	SMALL	INSENSITIVE	LARGE	INSENSITIVE

CONCLUSIONS/RECOMMENDATIONS

EPA

THERE IS LITTLE WE CAN DO EXCEPT LEARN TO ADAPT TO A WARMER CLIMATE.
LEGISLATION IS UNLIKELY TO HAVE MUCH EFFECT.

NRC/NAS

WE MUST RESOLVE UNCERTAINTIES THROUGH RESEARCH. ENERGY TAXES CAN HAVE AN
IMPACT.

LEGISLATION IS PREMATURE.

MIT/STANFORD

WE MUST START TALKING TO POLICY MAKERS. SUGGEST EXTREME REDUCTION IN
FOSSIL FUEL USE THROUGH CONSERVATION AND ALTERNATE TECHNOLOGIES USING
ELECTRICITY. NUCLEAR CAN HAVE IMPACT.

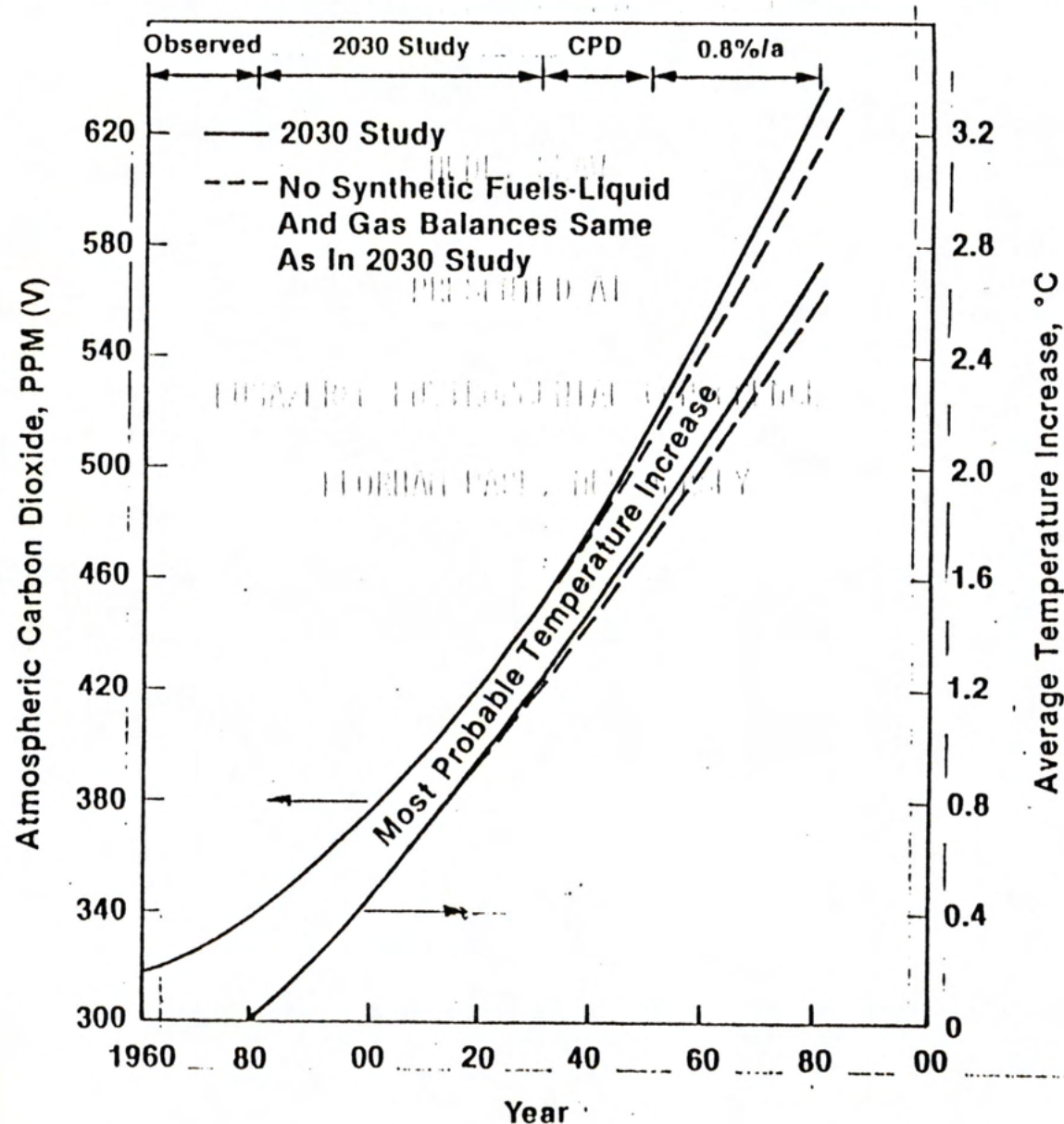
INTERNATIONAL DEBATE ON LEGISLATION IS NEEDED.

EXXON

THERE IS ADEQUATE TIME TO STUDY THE PROBLEM.

LEGISLATION IS PREMATURE.

GROWTH OF ATMOSPHERIC CO₂ AND INSTANTANEOUS GLOBAL TEMPERATURE INCREASE AS A FUNCTION OF TIME



QUANTITY OF CO₂ PRODUCED FROM FUELS

MtC/EJ PRODUCT (% EFFICIENCY)

<u>FUEL</u>	<u>PRODUCTION</u>	<u>REFINING</u>	<u>COMBUSTION</u>	<u>TOTAL</u>	<u>RATIO TO GAS</u>
COAL	-	-	24.3	24.3	1.8
PETROLEUM					
GASOLINE	-	5.5(90)	18.8	24.3	1.8
FUEL OIL		1.9(95)	19.9	21.8	1.6
NATURAL GAS	-	-	13.5	13.5	1.0
COAL SYNTHETICS					
H-COAL (GASOLINE)	18.5(65)	17.2(75)	18.8	54.5	4.1
EDS (GASOLINE)	18.5(65)	13.5(80)	18.8	50.8	3.8
SNG	27 (60)	-	13.5	40.5	3.0
SHALE OIL (GASOLINE)	13.9(75)	6.5(88)	18.8	39.2	2.9
ELECTRICITY FROM COAL	67.4(36)			67.4	5.0

CO₂ GREENHOUSE AND CLIMATE ISSUES

AS PART OF CPPD'S TECHNOLOGY FORECASTING ACTIVITIES IN 1981, I WROTE A CO₂ GREENHOUSE FORECAST BASED ON PUBLICALLY AVAILABLE INFORMATION. SOON THEREAFTER, S&T REQUESTED AN UPDATE OF THE FORECAST USING EXXON FOSSIL FUEL PROJECTIONS. THIS REQUEST WAS FOLLOWED LATE IN 1981 WITH A REQUEST BY CPD FOR ASSISTANCE IN EVALUATING THE POTENTIAL IMPACT OF THE CO₂ EFFECT IN THE "2030 STUDY". AFTER MEETING CPD'S SPECIFIC NEED, A FORMAL TECHNOLOGY FORECAST UPDATE WAS ISSUED TO S&T IN THE BEGINNING OF APRIL 1982. IT WAS SUBSEQUENTLY SENT FOR REVIEW TO THE EXXON AFFILIATES. THE PRIMARY FOSSIL FUEL VOLUMETRIC PROJECTIONS WERE CONVERTED TO AN ENERGY BASIS IN QUADS/YEAR, AS SHOWN ON THE FIRST VUGRAPH. SINCE SHALE LOSSES WERE NOT INCLUDED BY CPD, THEY WERE ESTIMATED AND ADDED TO OIL ENERGY. THE TOTAL CARBON CONTENT PER UNIT ENERGY OF THE U.S. RESOURCES OF COAL AND OIL SHALE WERE AVERAGED IN ORDER TO CALCULATE LBS. CO₂/MBTU FOR EACH RESOURCE:

	<u>RATIO</u>
OIL = 170 LBS. CO ₂ /MBTU	1.5
GAS = 115	1.0
COAL = 207	1.8

THESE NUMBERS WERE CHECKED AGAINST SOME INFORMATION ON WORLD RESOURCES AND FOUND TO BE ADEQUATE.

VG-2 WE THEN ESTIMATED THE TOTAL CO₂ EMITTED FROM THE OXIDATION OF THESE
FUELS, AS SHOWN IN THIS VUGRAPH. THIS IS A SEMILOG PLOT WHICH TENDS TO
PICTORIALLY OVEREMPHASIZE THE IMPORTANCE OF GAS. WE CHOOSE THIS TYPE OF GRAPH
TO ENABLE US TO SHOW CERTAIN DETAILS THAT WOULD BE HARD TO DETECT ON A LINEAR
PLOT. THE RATE OF CO₂ EMISSIONS GROWS AT ABOUT A 20% HIGHER RATE THAN
ENERGY. THIS IS DUE, IN PART, TO THE SHARP INCREASES IN THE USE OF COAL.
OTHER FACTORS THAT CONTRIBUTE TO THE HIGHER CARBON GROWTH RATE ARE SHOWN ON
OL-1 OVERLAY #1 AND INCLUDE THE ENTRAINED CO₂ ASSOCIATED WITH NATURAL GAS IN GAS
(RED) PRODUCTION GROWING FROM ABOUT 5% TO 15% IN 2050. SIMILARLY, U.S. OIL SHALES
CONTAIN A FAIR AMOUNT OF CARBONATE-CONTAINING MINERALS CONSISTING PRIMARILY OF
LIMESTONE AND DOLOMITE WHICH DECOMPOSE AS A FUNCTION OF RETORTING TEMPERATURE,
FROM 25% AT RELATIVELY LOW TEMPERATURES SUCH AS CONVENTIONAL RETORTING TO 100%
AT ELEVATED TEMPERATURES. WE ASSUMED, VERY CONSERVATIVELY, THAT 65% OF THE
CARBONATE-CONTAINING MINERALS WOULD DECOMPOSE IN PRODUCING SHALE OIL. THE CO₂
IN GAS PRODUCTION WAS ADDED TO THE CO₂ EMISSIONS FROM GAS, AND THE SHALE
CARBONATE DECOMPOSITION WAS ADDED TO CO₂ EMISSIONS FROM OIL. IN ADDITION, THE
PROCESSING OF COAL AND OIL SHALE TO FUELS RESULTS IN A FAIR AMOUNT OF CO₂
OL-2 PRODUCTION. THIS IS SHOWN ON OVERLAY #2.
(BLUE)

VG-2 THE CLIMATIC EFFECT OF NOT HAVING A SYNFUELS INDUSTRY AND NOT
EMITTING CO₂ IN NATURAL GAS PRODUCTION, I.E., SUBTRACTING THE CO₂ PRODUCED
FROM THE SOURCES MENTIONED IN THE TWO OVERLAYS OF VUGRAPH #2, WOULD BE TO
DELAY THE DOUBLING TIME BY ABOUT 5 YEARS.

OUR NEXT TASK IS TO CONVERT THE AMOUNT OF CO₂ EMITTED FROM FOSSIL FUEL OXIDATION INTO A PROJECTION OF HOW IT MAY IMPACT ON CLIMATE. THIS, HOWEVER, REQUIRES A NUMBER OF ASSUMPTIONS. FIRST OF ALL, WE MUST ESTIMATE HOW MUCH OF THE CO₂ STAYS IN THE ATMOSPHERE. THIS MUST BE CHECKED BY CONDUCTING A CARBON BALANCE AROUND THE EARTH. WE ASSUMED THAT ABOUT 1/2 OF THE CO₂ GENERATED FROM FOSSIL FUELS REMAINS IN THE ATMOSPHERE. THIS IS A CONSERVATIVE ASSUMPTION SINCE A FAIR AMOUNT OF CO₂ CAN BE TRACED TO DEFORESTATION. SECOND, WE MUST ESTIMATE HOW MUCH CO₂ EXISTED IN THE ATMOSPHERE PRIOR TO THE INDUSTRIAL REVOLUTION BECAUSE CO₂ CONCENTRATION WAS ASSUMED CONSTANT UP TO THAT TIME. THERE ARE TWO SCHOOLS OF THOUGHT, DEPENDING ON THE METHOD OF CHEMICAL ANALYSIS. ISOTOPE MEASUREMENTS IN TREE-RINGS INDICATE THAT THE ATMOSPHERE CONTAINED 260 TO 270 PPM CO₂ PRIOR TO THE INDUSTRIAL REVOLUTION. CORRECTIONS TO MEASUREMENTS ACTUALLY CARRIED OUT ABOUT THAT TIME INDICATE THE CONCENTRATION TO HAVE BEEN 290 TO 300 PPM CO₂. THIRD, WE MUST ESTIMATE WHEN THE CO₂ EFFECT WILL EXCEED THE CLIMATIC NOISE THRESHOLD OF 0.5°C.

VG-3 A GRAPH SHOWING ALL THESE ASSUMPTIONS IS REPRODUCED ON THE LAST VUGRAPH. MOST CLIMATOLOGISTS ASSUME THAT THE CO₂ EFFECT WILL BE DETECTABLE BY THE YEAR 2000. IF SO, WE MUST TAKE INTO ACCOUNT THAT IT TAKES ABOUT TWO DECADES TO EQUILIBRATE THE OCEANS TO A NEW TEMPERATURE. THUS, THE THRESHOLD WOULD OCCUR AT 340 PPM CO₂ AND WOULD CAUSE A TEMPERATURE RISE OF 3°C IN 2090 WHEN THE CURRENT AMOUNT OF ATMOSPHERIC CO₂ WOULD DOUBLE, IF THE PRE-INDUSTRIAL CONCENTRATION HAD BEEN BETWEEN 290 AND 300 PPM. IF THE PREINDUSTRIAL CO₂ HAD BEEN BETWEEN 260 AND 270 PPM, THEN A DOUBLING WOULD CAUSE A 2°C RISE IN GLOBAL AVERAGE TEMPERATURE. THESE VALUES FALL TOWARD THE LOWER END OF THE GENERALLY ACCEPTED TEMPERATURE RANGE FOR A DOUBLING OF $3 \pm 1.5^\circ\text{C}$, AND ARE CONSISTENT WITH THE RECENTLY PUBLISHED 50TH PERCENTILE LINE IN THE NAS REPORT.

A 2 TO 3°C INCREASE IN GLOBAL AVERAGE TEMPERATURE CAN BE AMPLIFIED TO ABOUT 10°C AT THE POLES. THIS COULD CAUSE POLAR ICE MELTING AND A POSSIBLE SEA-LEVEL RISE OF 0.7 METER BY 2080. THE TIME SCALE FOR SUCH A CATASTROPHE IS MEASURED IN CENTURIES. OTHER POTENTIAL EFFECTS ASSOCIATED WITH A HIGH ATMOSPHERIC CO₂ CONCENTRATION AND A WARMER CLIMATE ARE:

- REDISTRIBUTION OF RAINFALL
- POSITIVE AND NEGATIVE CHANGES IN AGRICULTURAL PRODUCTIVITY
- ACCELERATED GROWTH OF PESTS AND WEEDS
- DETRIMENTAL HEALTH EFFECTS
- POPULATION MIGRATION

SOCIETY MUST CAREFULLY STUDY THE PROBLEM IN ORDER TO ESTABLISH A DESIRABLE COURSE OF ACTION. WE CAN EITHER ADAPT OUR CIVILIZATION TO A WARMER PLANET OR AVOID THE PROBLEM BY SHARPLY CURTAILING THE USE OF FOSSIL FUELS. THE GENERAL CONSENSUS IS THAT SOCIETY HAS SUFFICIENT TIME TO TECHNOLOGICALLY ADAPT TO A CO₂ GREENHOUSE EFFECT.

OUR CONCLUSION WAS REAFFIRMED BY A NUMBER OF STUDIES WHICH RECEIVED WIDE PRESS PUBLICITY. THESE STUDIES INCLUDE THOSE OF THE EPA, NRC/NAS, AND MIT/NSF AND ARE SUMMARIZED IN THE NEXT 4 VU-GRAPHS.