CO_2 GREENHOUSE AND CLIMATE ISSUES

HENRY SHAW

PRESENTED AT

EUSA/ER&E ENVIRONMENTAL CONFERENCE

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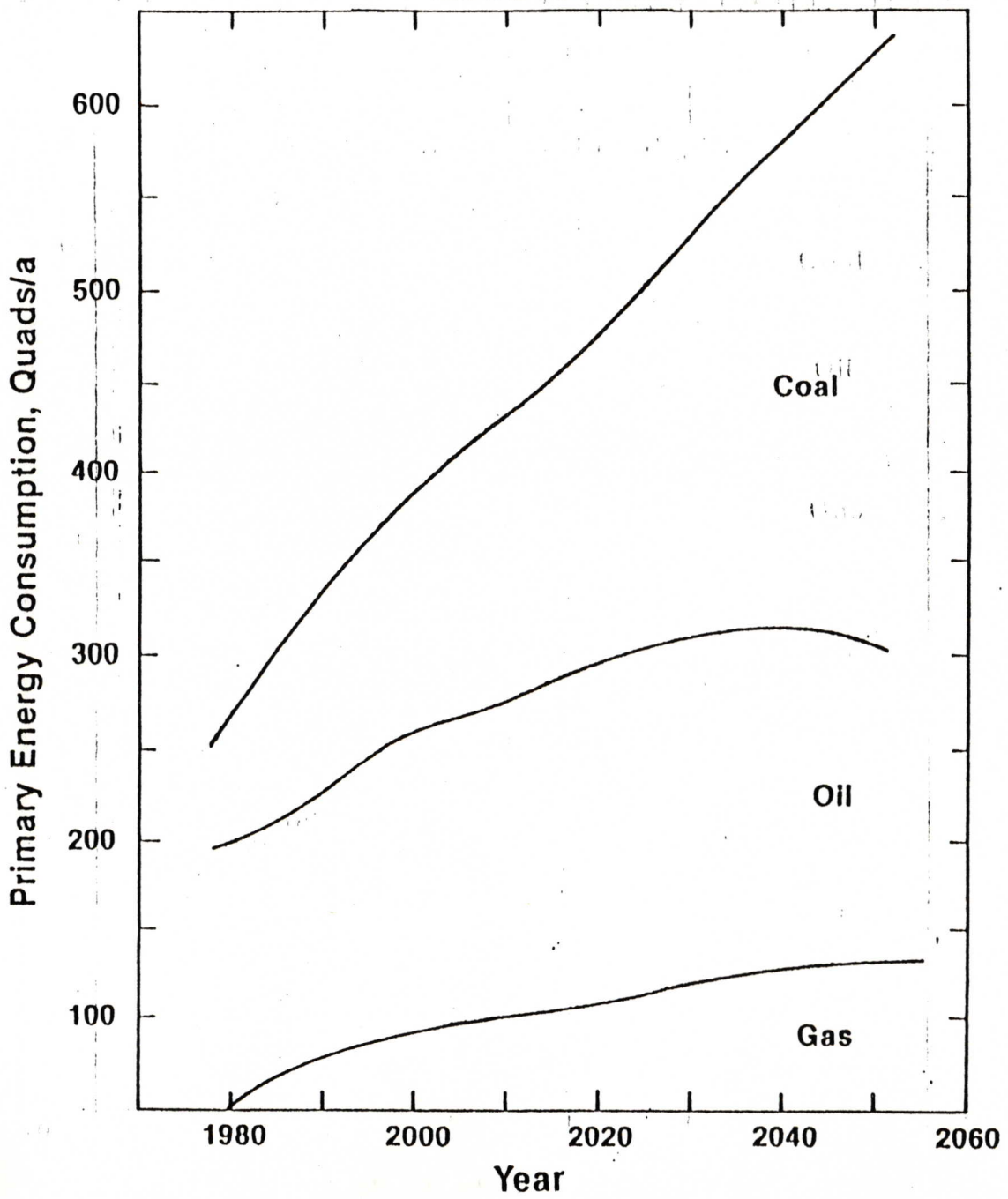
PRIMARY FOSSIL FUEL ENERGY CONSUMPTION
2030 STUDY



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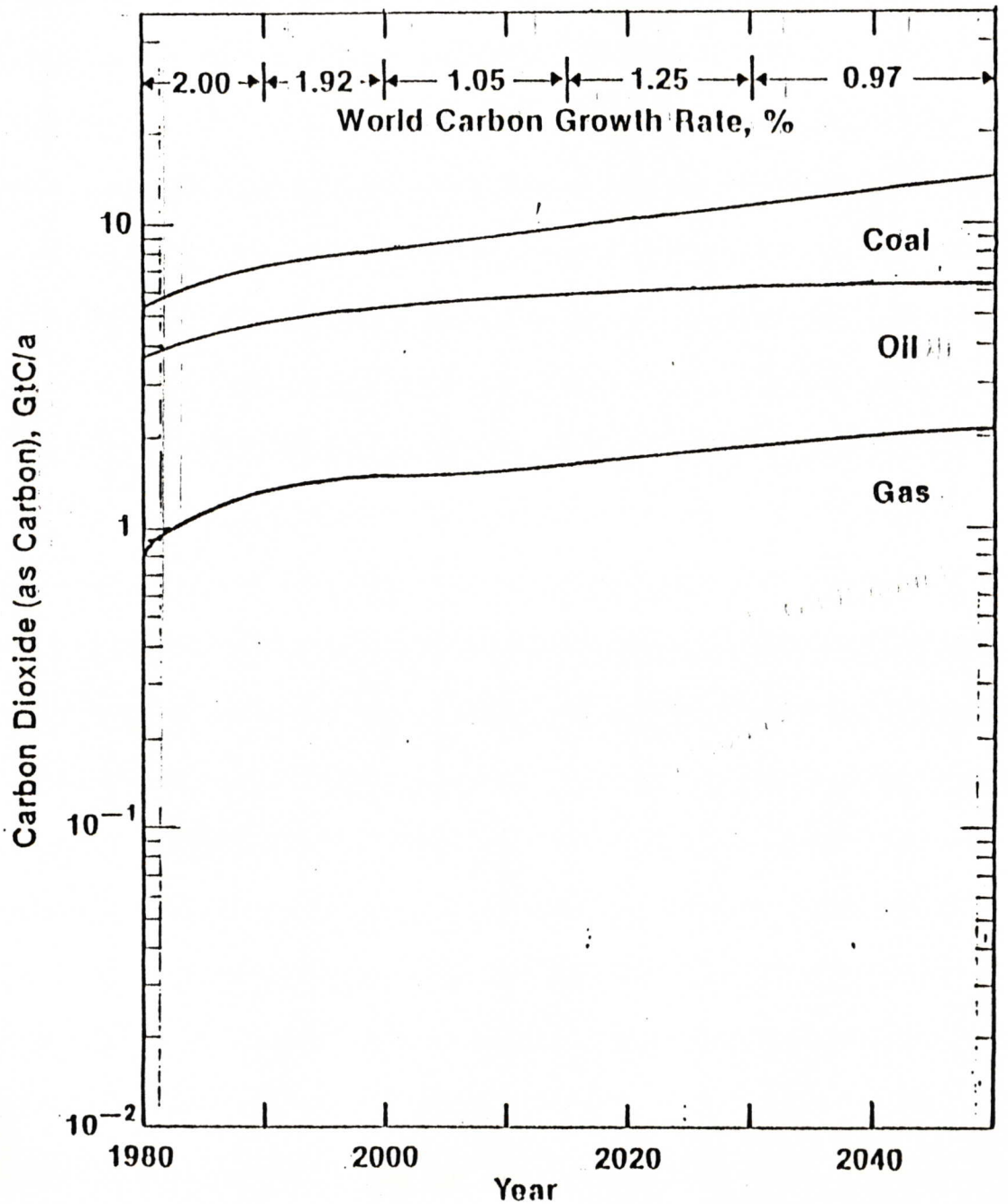
PROJECTED CARBON DIOXIDE (AS CARBON) FROM WORLD PRIMARY FOSSIL FUEL CONSUMPTION



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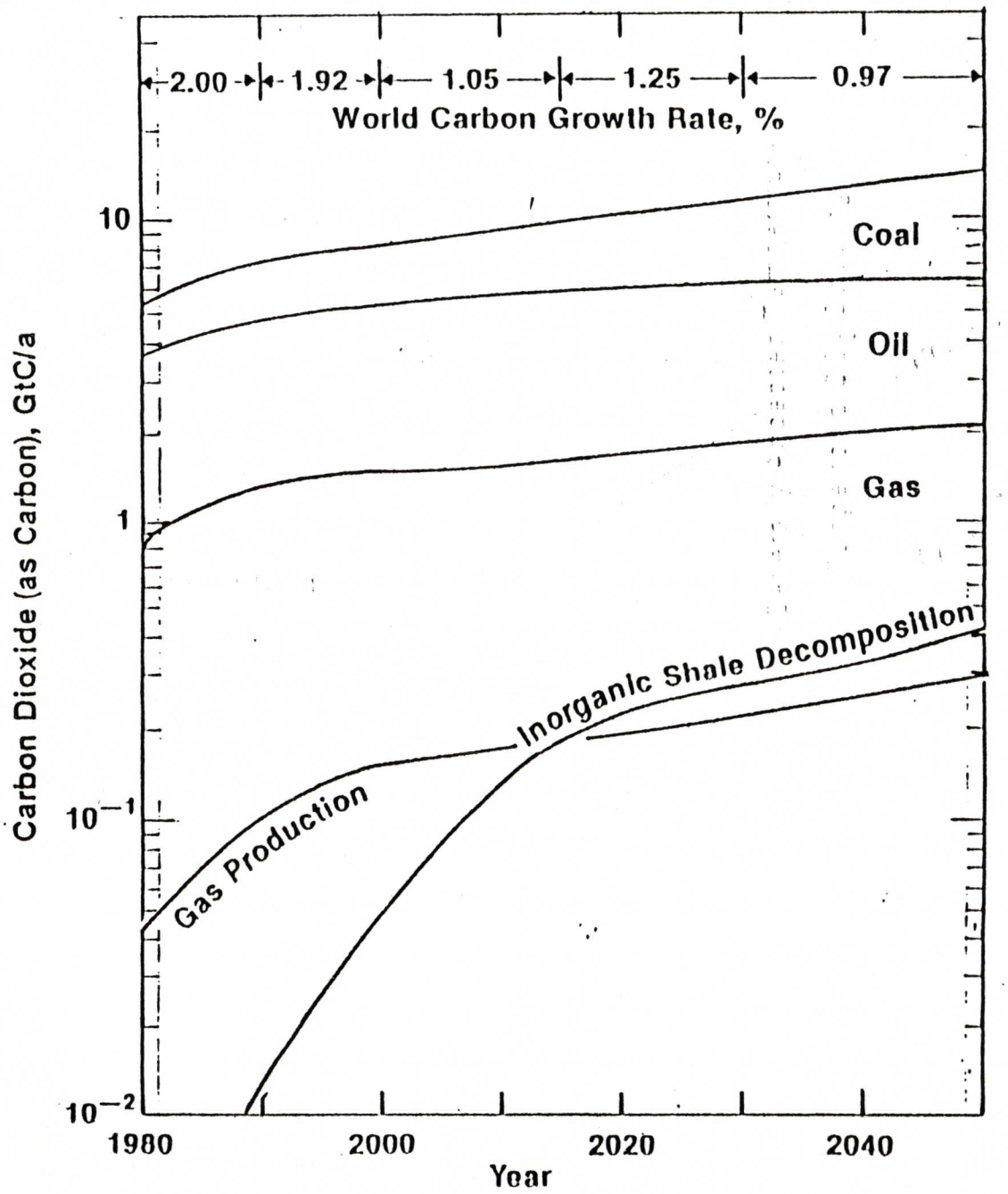

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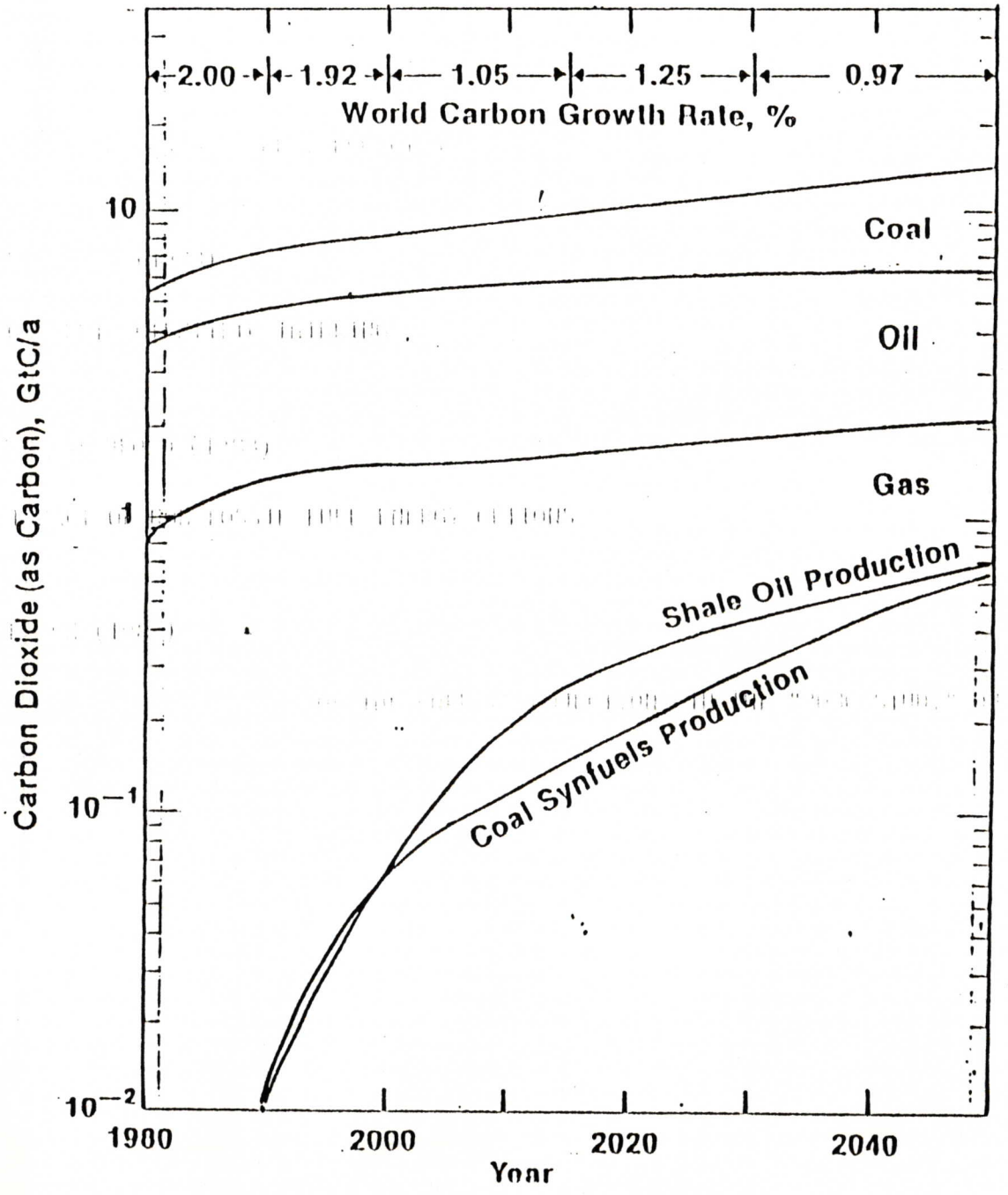


RESULTS/EFFECTS

	EPA	NRC/NAS	MIT	EXXON
• TIME FOR CO_2 DOUBLING	2060	2075	-	2090
• AVERAGE TEMPERATURE RISE	3^oC	$\sim 2^oC$	$1.5\text{-}4.5^oC$	$1.3 - 3.1^oC$
• OTHER GASES IMPACT	-1.6 to 3.3^oC	$\sim 1^oC$	-	-
• SEA LEVEL RISE	150 cm, 2040 215 cm, 2100	70 cm 2080 ($3\text{-}4^oC$ 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.

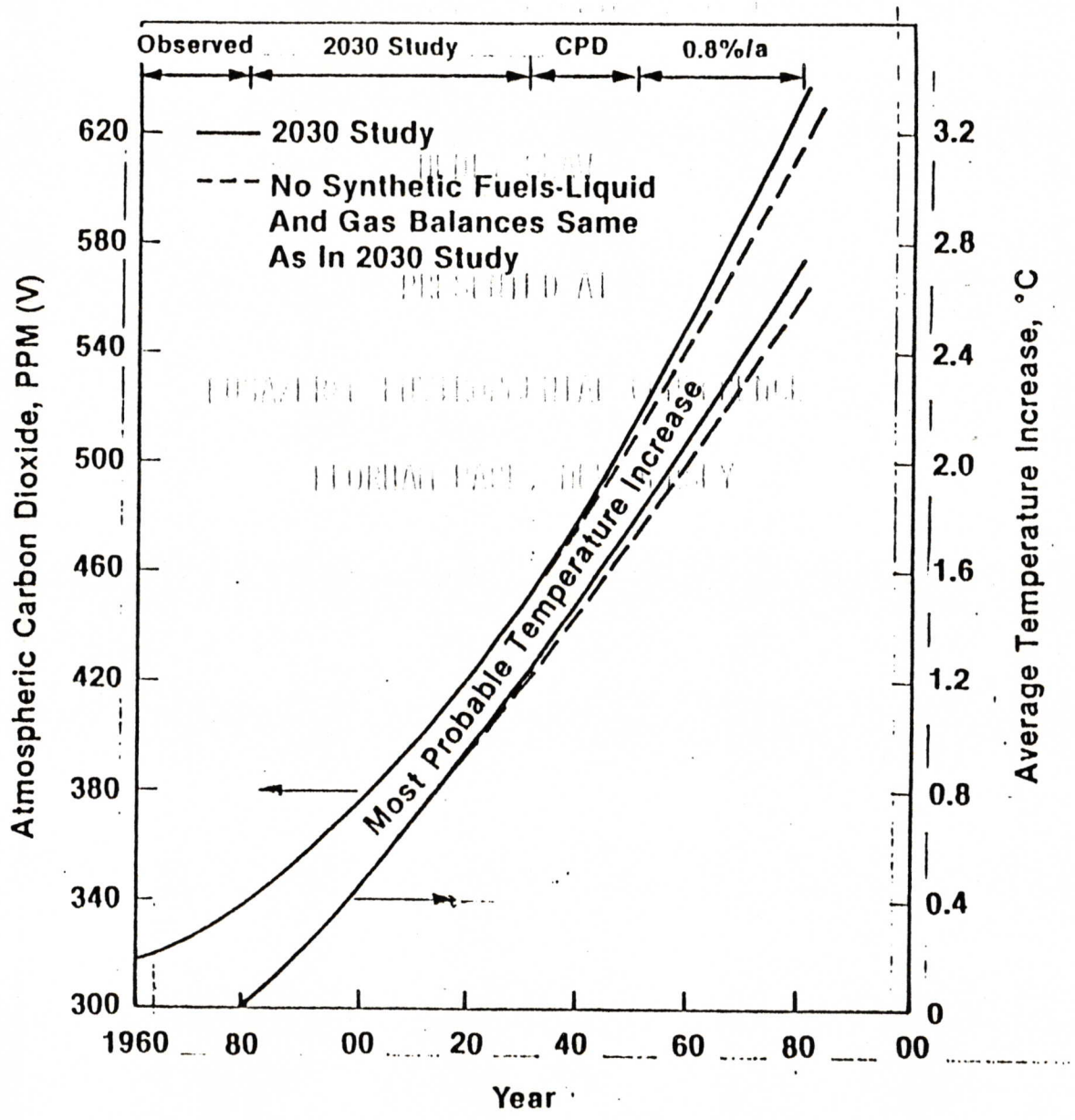
EXXON

THERE IS ADEQUATE TIME TO STUDY THE PROBLEM.

LEGISLATION IS PREMATURE.

BACK - UP

GROWTH OF ATMOSPHERIC CO_2 AND INSTANTANEOUS GLOBAL TEMPERATURE INCREASE AS A FUNCTION OF TIME



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QUANTITY OF CO_2 PRODUCED FROM FUELS

MTC/EJ PRODUCT (% EFFICIENCY)

FUEL	PRODUCTION	REFINING	COMBUSTION	TOTAL	RATIO TO GAS
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

CO_2 GREENHOUSE AND CLIMATE ISSUES

AS PART OF CPPD's TECHNOLOGY FORECASTING ACTIVITIES IN 1981, I WROTE A CO_2 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 CO_2 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

VG-1 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. CO_2/MBTU FOR EACH RESOURCE:

		RATIO
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.

WE THEN ESTIMATED THE TOTAL CO_2 EMITTED FROM THE OXIDATION OF THESE

VG-2 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 CO_2 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 (RED) OVERLAY #1 AND INCLUDE THE ENTRAINED CO_2 ASSOCIATED WITH NATURAL GAS IN GAS 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 CO_2 IN GAS PRODUCTION WAS ADDED TO THE CO_2 EMISSIONS FROM GAS, AND THE SHALE CARBONATE DECOMPOSITION WAS ADDED TO CO_2 EMISSIONS FROM OIL. IN ADDITION, THE PROCESSING OF COAL AND OIL SHALE TO FUELS RESULTS IN A FAIR AMOUNT OF CO_2

OL-2 (BLUE) PRODUCTION. THIS IS SHOWN ON OVERLAY #2.

THE CLIMATIC EFFECT OF NOT HAVING A SYNFUELS INDUSTRY AND NOT EMITTING CO_2 IN NATURAL GAS PRODUCTION, I.E., SUBTRACTING THE CO_2 PRODUCED

VG-2 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 AMOUTN OF CO_2 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 CO_2 STAYS IN THE ATMOSPHERE. THIS MUST BE CHECKED BY CONDUCTING A CARBON BALANCE AROUND THE EARTH. WE ASSUMED THAT ABOUT 1/2 OF THE CO_2 GENERATED FROM FOSSIL FUELS REMAINS IN THE ATMOSPHERE. THIS IS A CONSERVATIVE ASSUMPTION SINCE A FAIR AMOUNT OF CO_2 CAN BE TRACED TO DEFORESTATION. SECOND, WE MUST ESTIMATE HOW MUCH CO_2 EXISTED IN THE ATMOSPHERE PRIOR TO THE INDUSTRIAL REVOLUTION BECAUSE CO_2 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 CO_2 PRIOR TO THE INDUSTRIAL REVOLUTION. CORRECTIONS TO MEASUREMENTS ACTUALLY CARRIED OUT ABOUT THAT TIME INDICATE THE CONCENTRATION TO HAVE BEEN 290 TO 300 PPM CO_2. THIRD, WE MUST ESTIMATE WHEN THE CO_2 EFFECT WILL EXCEED THE CLIMATIC NOISE THRESHOLD OF $0.5^{o}C$.

A GRAPH SHOWING ALL THESE ASSUMPTIONS IS REPRODUCED ON THE LAST

VG-3 VUGRAPH. MOST CLIMATOLOGISTS ASSUME THAT THE CO_2 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 CO_2 AND WOULD CAUSE A TEMPERATURE RISE OF $3^{o}C$ IN 2090 WHEN THE CURRENT AMOUNT OF ATMOSPHERIC CO_2 WOULD DOUBLE, IF THE PRE-INDUSTRIAL CONCENTRATION HAD BEEN BETWEEN 290 AND 300 PPM. IF THE PREINDUSTRIAL CO_2 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 $3 \pm 1.5^{o}C$, 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 CO_2 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 CONCENSUS IS THAT SOCIETY HAS SUFFICIENT TIME TO TECHNOLOGICALLY ADAPT TO A CO_2 GREENHOUSE EFFECT.

OUR CONCLUSION WAS RECENTLY 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.