

ENERGY, GLOBAL WARMING AND POWER ELECTRONICS

**KEYNOTE ADDRESS
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**Department of Electrical Engineering
Indian Institute of Technology, Roorkee, India**

**By
Prof. Bimal K. Bose
Department of Electrical Engineering and Computer Science
The University of Tennessee
Knoxville, TN 37996-2100, USA
Tel: (865) 974-8398
Fax: (865) 974-5483
E-mail: bbose@utk.edu
Website: <http://web.eecs.utk.edu/~bose>**

ENERGY, GLOBAL WARMING, AND IMPACT OF POWER ELECTRONICS

IEEE DISTINGUISHED LECTURE PRESENTATION

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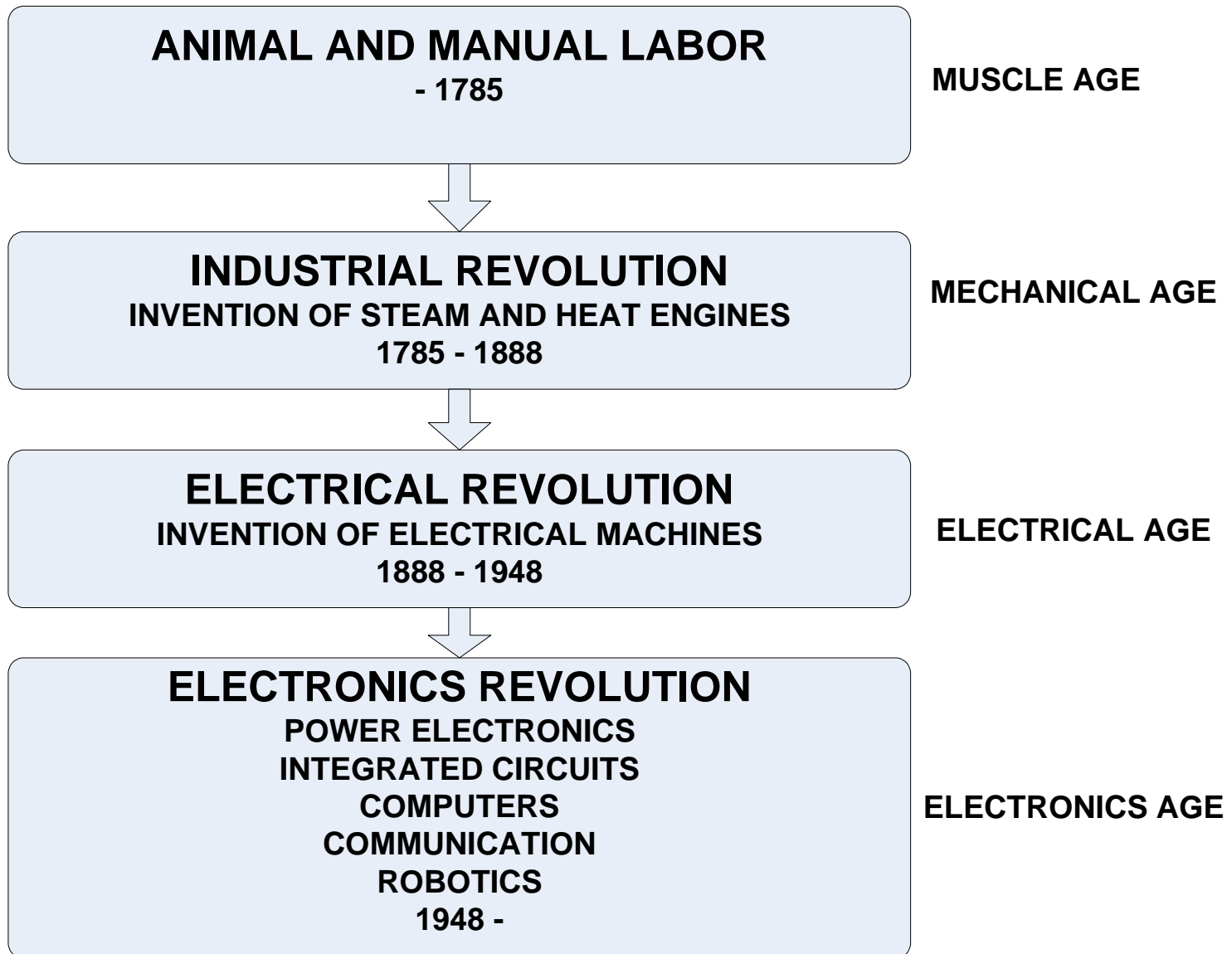
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Dr. Bimal K. Bose, *Life Fellow, IEEE*
Department of Electrical Engineering and Computer Science
The University of Tennessee
Knoxville, TN 37996-2100
Tel: (865) 974-8398
Fax: (865) 974-5483
E-Mail: bbose@utk.edu
Home Page: <http://web.eecs.utk.edu/~bose>

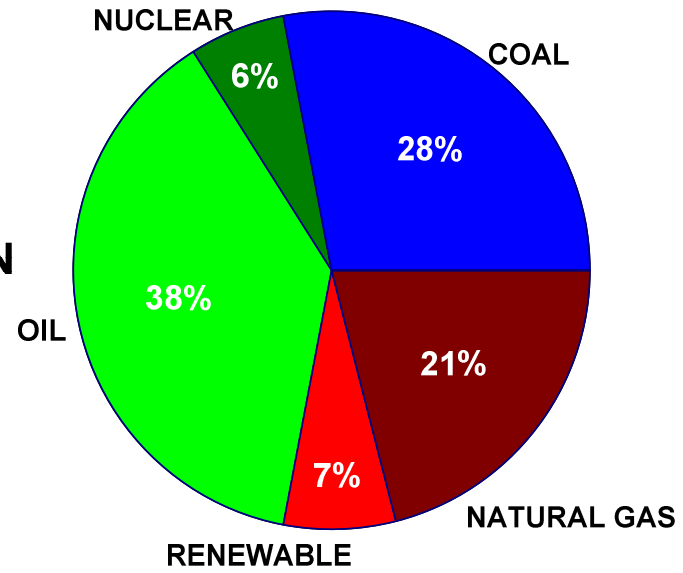
EVOLUTION OF INDUSTRIAL CIVILIZATION



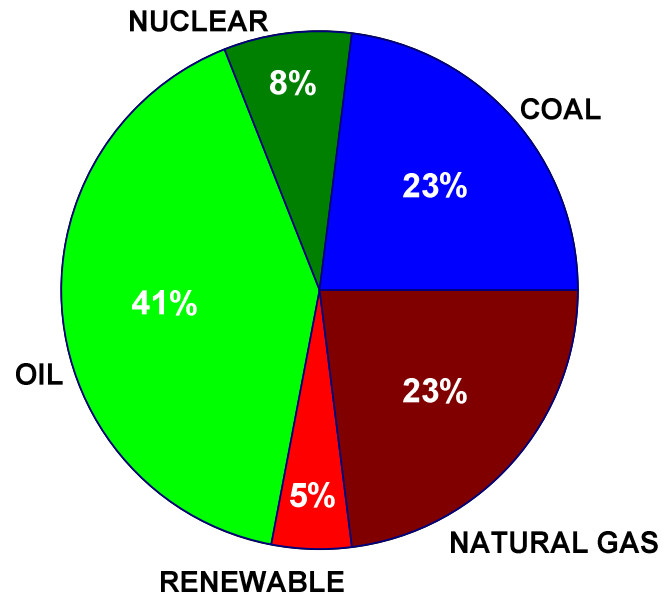
GLOBAL ENERGY CONSUMPTION SCENARIO

- **ENERGY IS THE LIFE-BLOOD FOR CONTINUAL PROGRESS OF HUMAN CIVILIZATION**
- **PER CAPITA ENERGY CONSUMPTION IS THE BAROMETER OF A NATION'S PROSPERITY**
- **GLOBAL ENERGY CONSUMPTION HAS INCREASED DRAMATICALLY TO ACCELERATE OUR LIVING STANDARD**
- **USA WITH 5% OF WORLD POPULATION CONSUMES 25% OF TOTAL ENERGY**
- **JAPAN WITH 2% WORLD POPULATION CONSUMES 5% OF TOTAL ENERGY**
- **CHINA AND INDIA WITH 35% OF WORLD POPULATION CONSUMES ONLY 3% OF TOTAL ENERGY**

GLOBAL ENERGY GENERATION



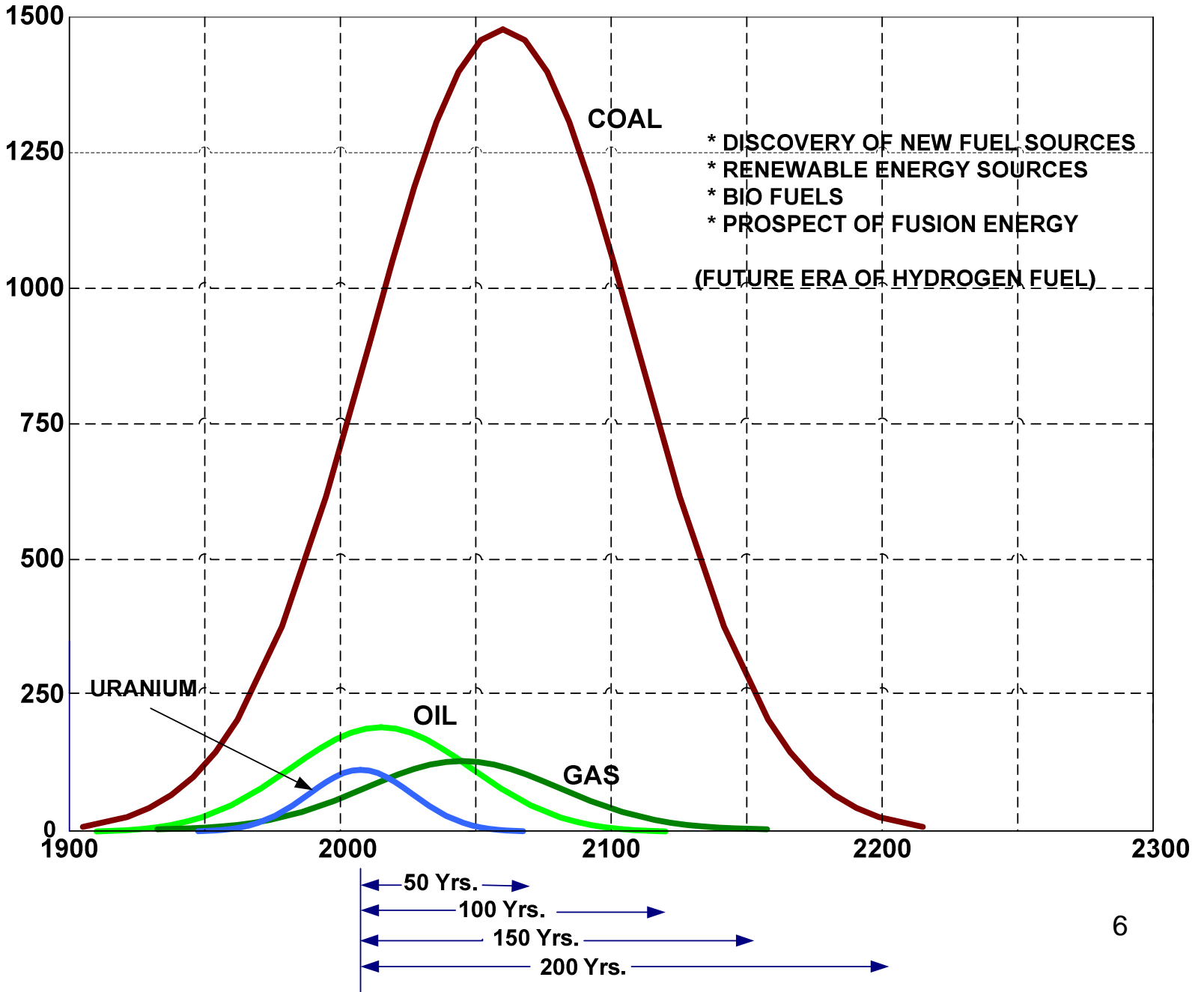
U.S. ENERGY GENERATION

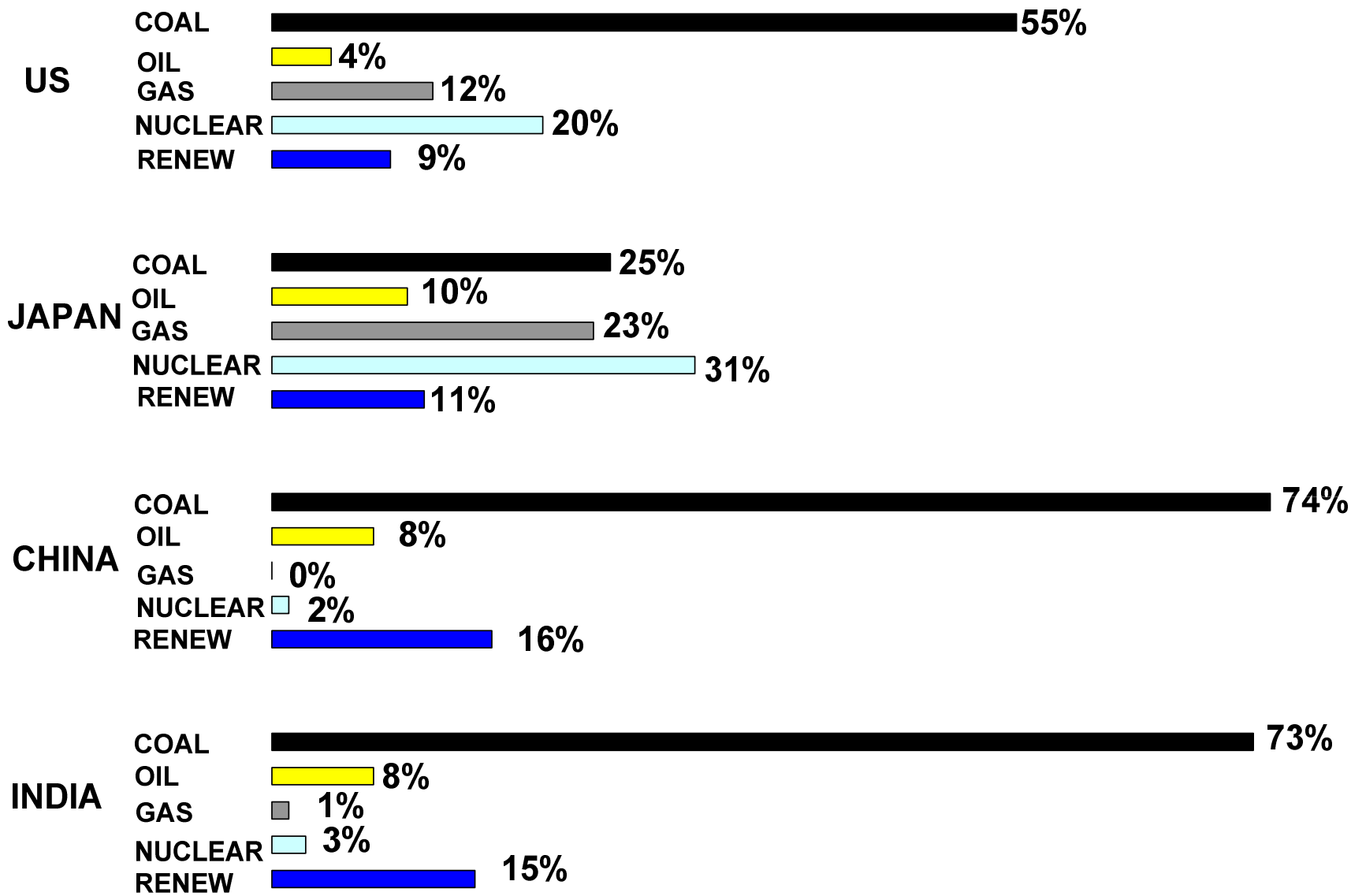


ENERGY GENERATION SCENARIO

PRODUCTION X 10¹⁸
JOULES

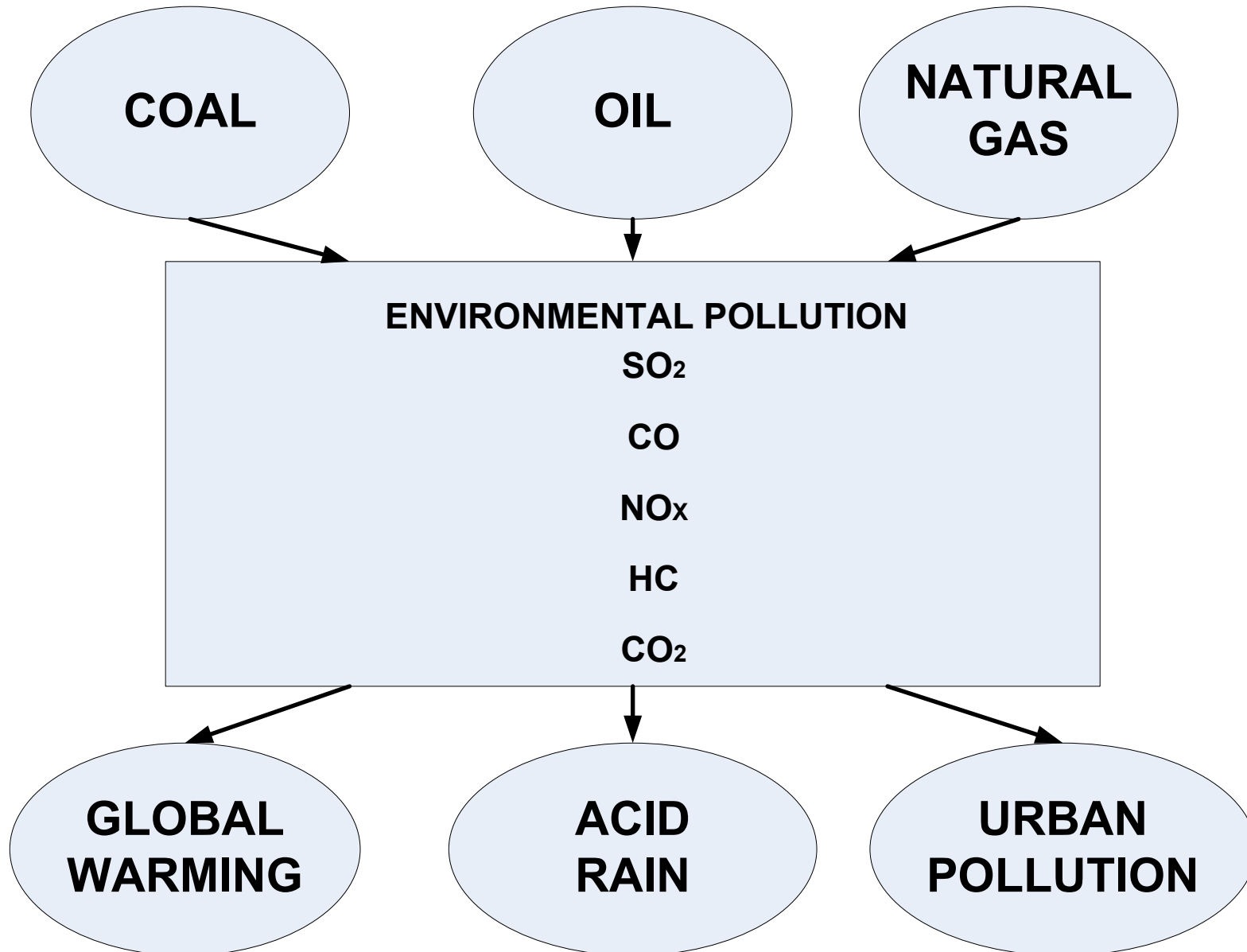
IDEALIZED ENERGY DEPLETION CURVES OF WORLD

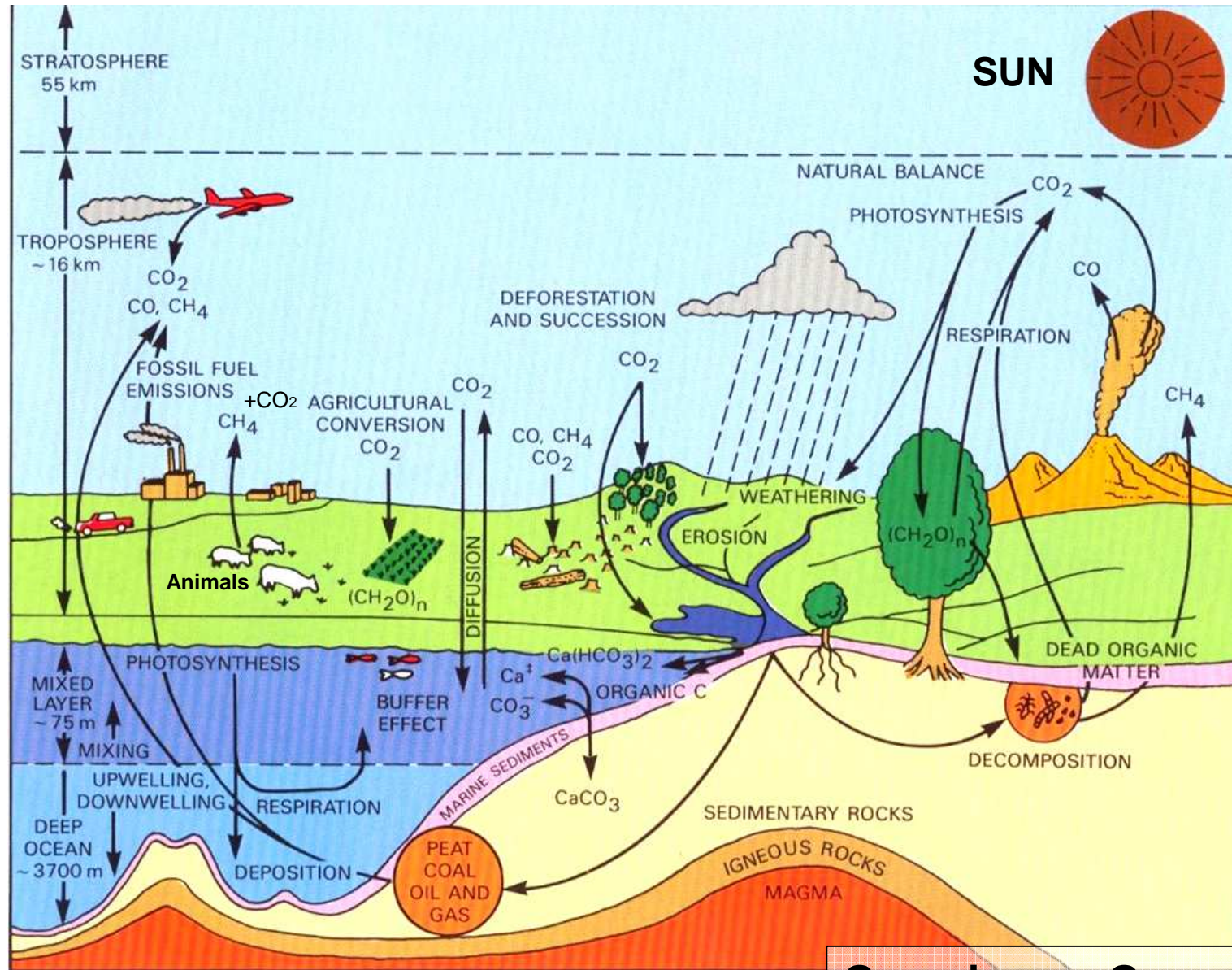




ELECTRICITY GENERATION BY FUEL TYPES FOR SELECTED COUNTRIES

ENVIRONMENTAL POLLUTION BY FOSSIL FUELS





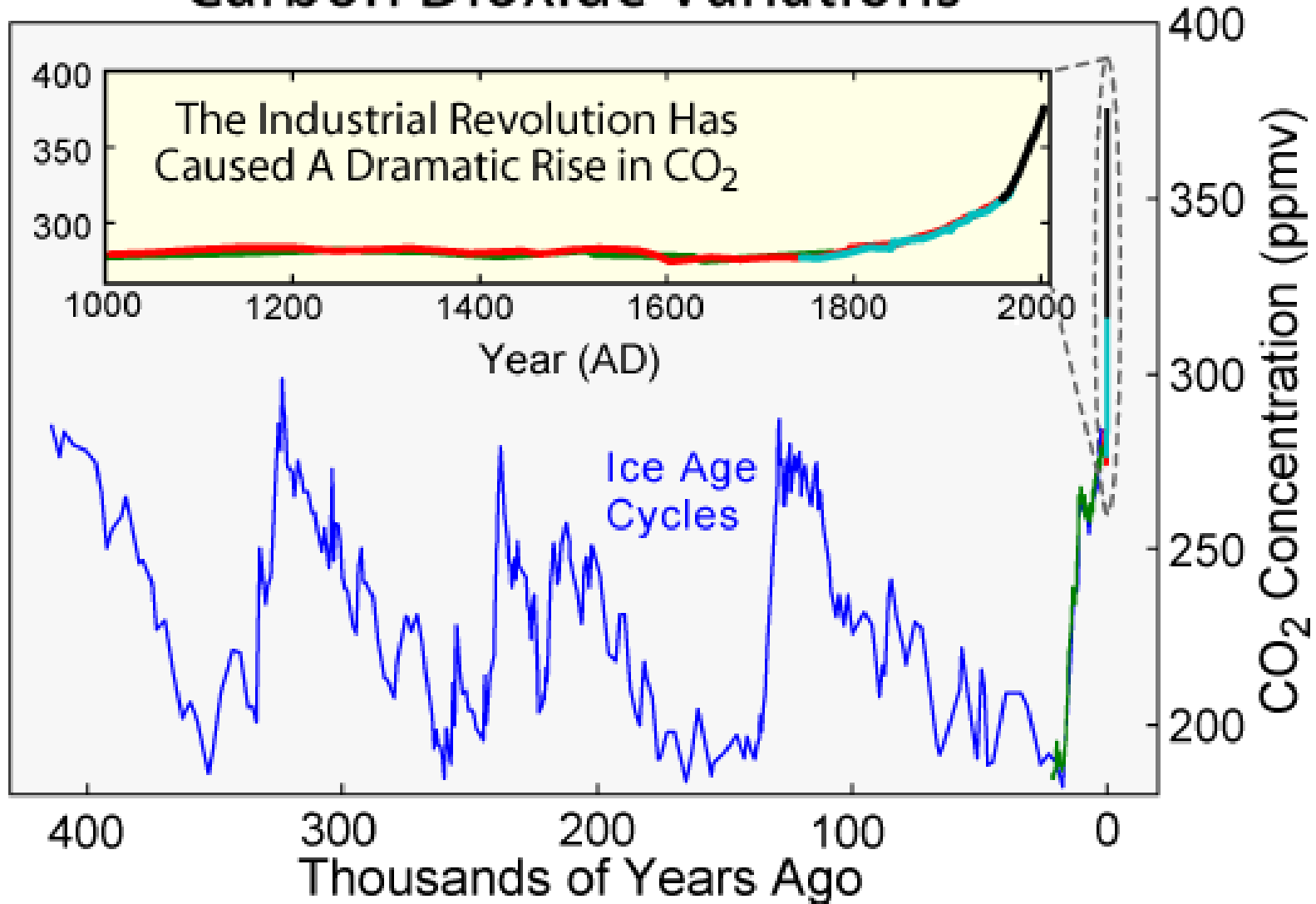
HOW GREENHOUSE GASES ARE GENERATED

- Greenhouse Gases**
- CO_2
 - Methane (CH_4)
 - Others

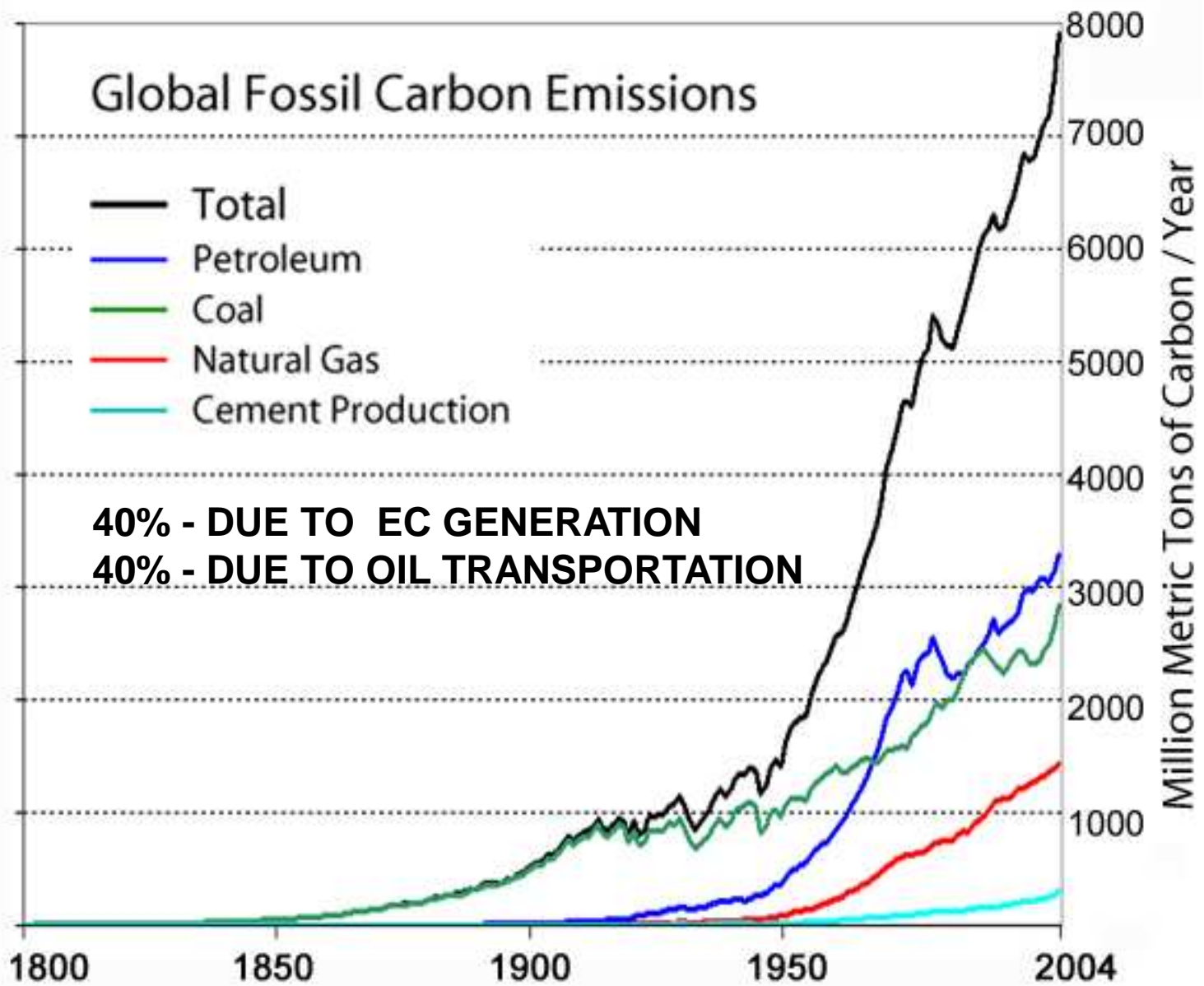
GLOBAL WARMING DUE TO GREEN HOUSE GASES

- **EARTH'S ATMOSPHERE ACCUMULATES SOLAR HEAT AND RAISES TEMPERATURE – GREEN HOUSE EFFECT (A FEW DEGREES IN 100 YEARS)**
- **MELTING OF GLACIERS AND POLAR ICE CAPS**
 - **CAUSING INUNDATION OF LOW- LYING AREAS**
- **ADVERSE EFFECT ON WORLD CLIMATE**
 - **SEVERE DROUGHTS IN TROPICAL COUNTRIES NEAR EQUATOR**
 - **DAMAGE TO AGRICULTURE AND VEGETATION**
 - **HURRICANES, TORNEDOS, HEAVY RAINS AND FLOODS**
 - **SPREAD OF DISEASES**
 - **SOME ANIMAL SPECIES MAY BE EXTINCT FROM EARTH (Ex. POLAR BEARS, PENGUINS, CORALS)**
- **ACIDITY INCREASE IN SEA WATER – THREAT TO MARINE LIFE**

Carbon Dioxide Variations

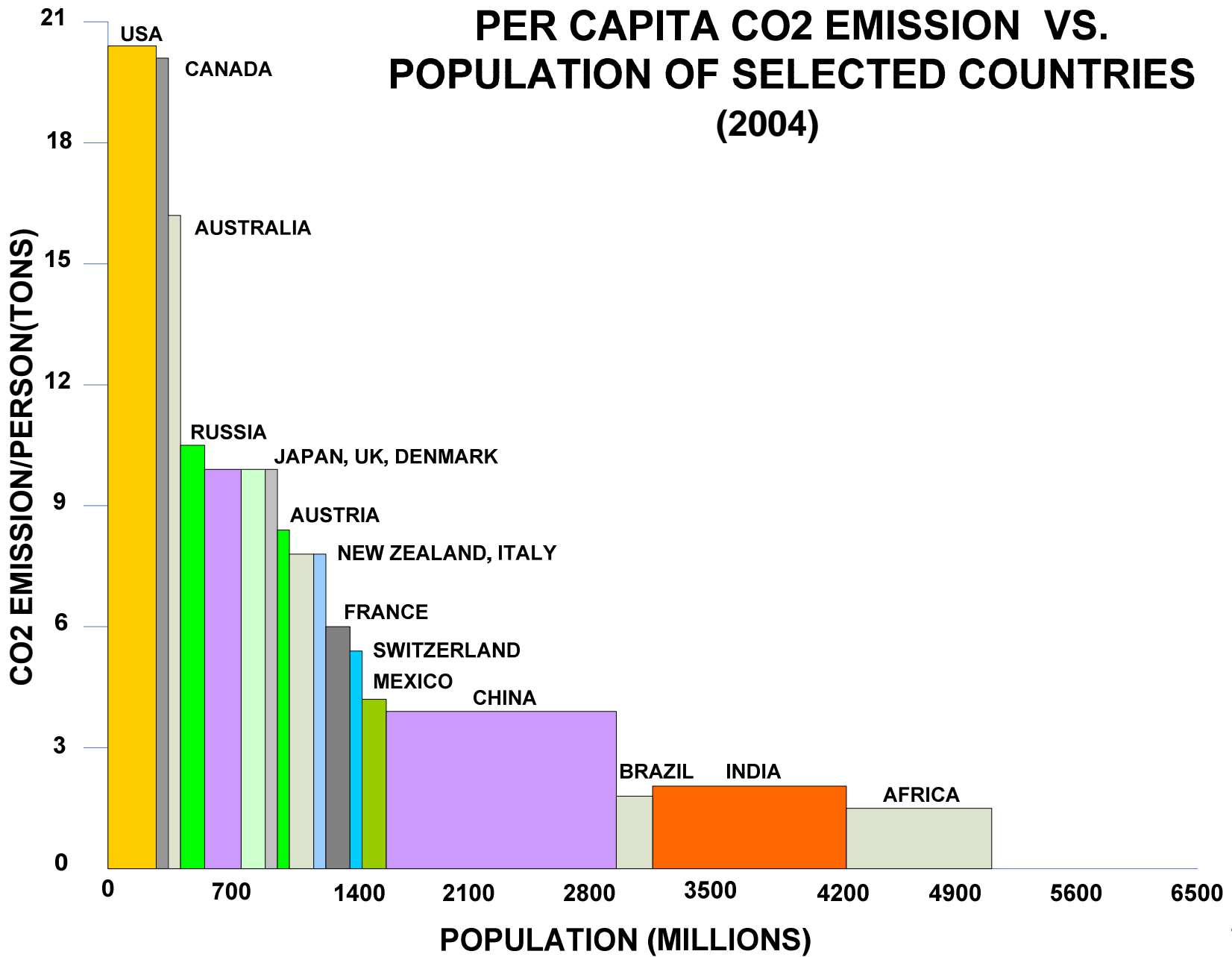


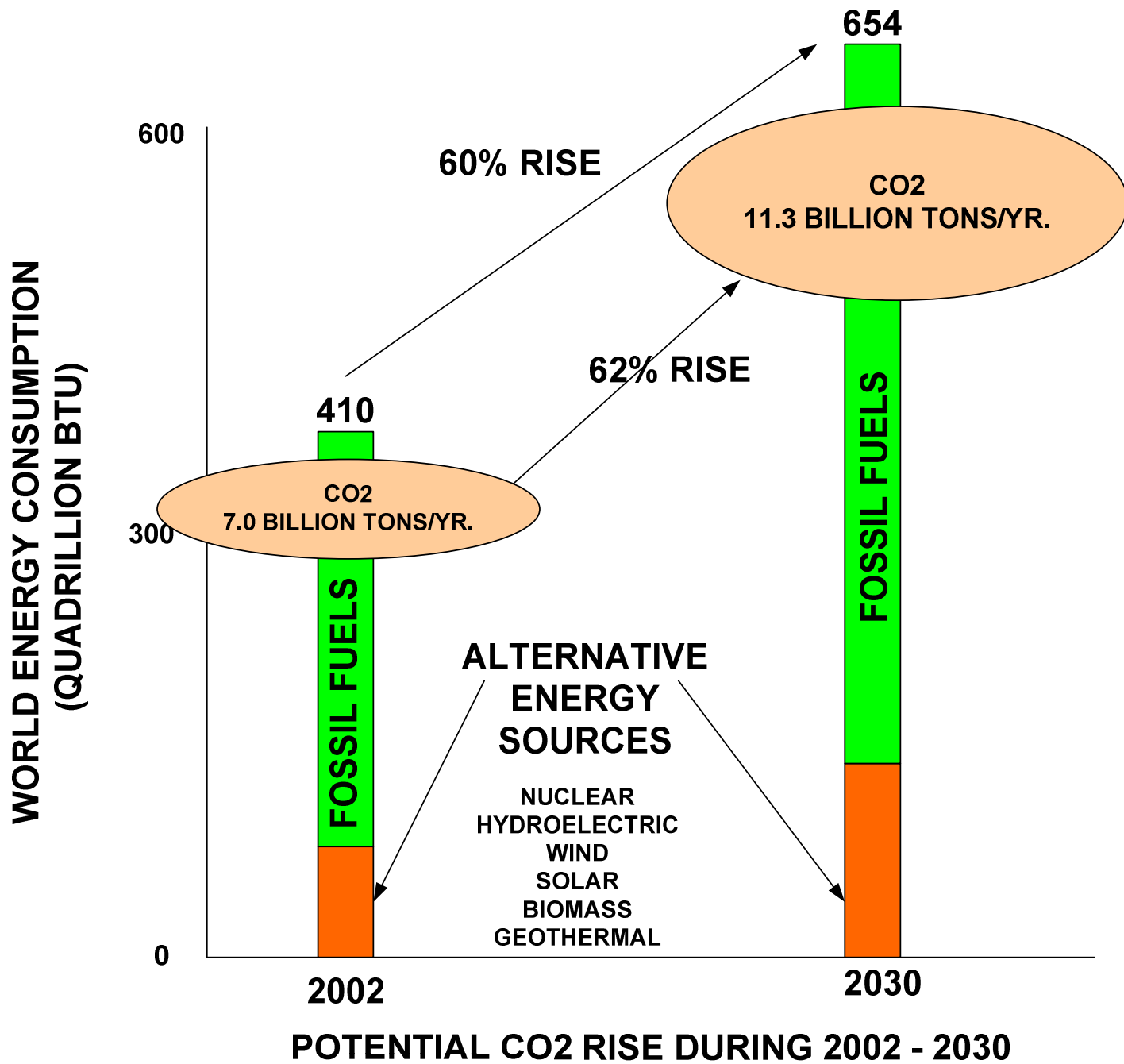
ATMOSPHERIC CO₂ CONCENTRATION FOR LAST 400,000 YEARS

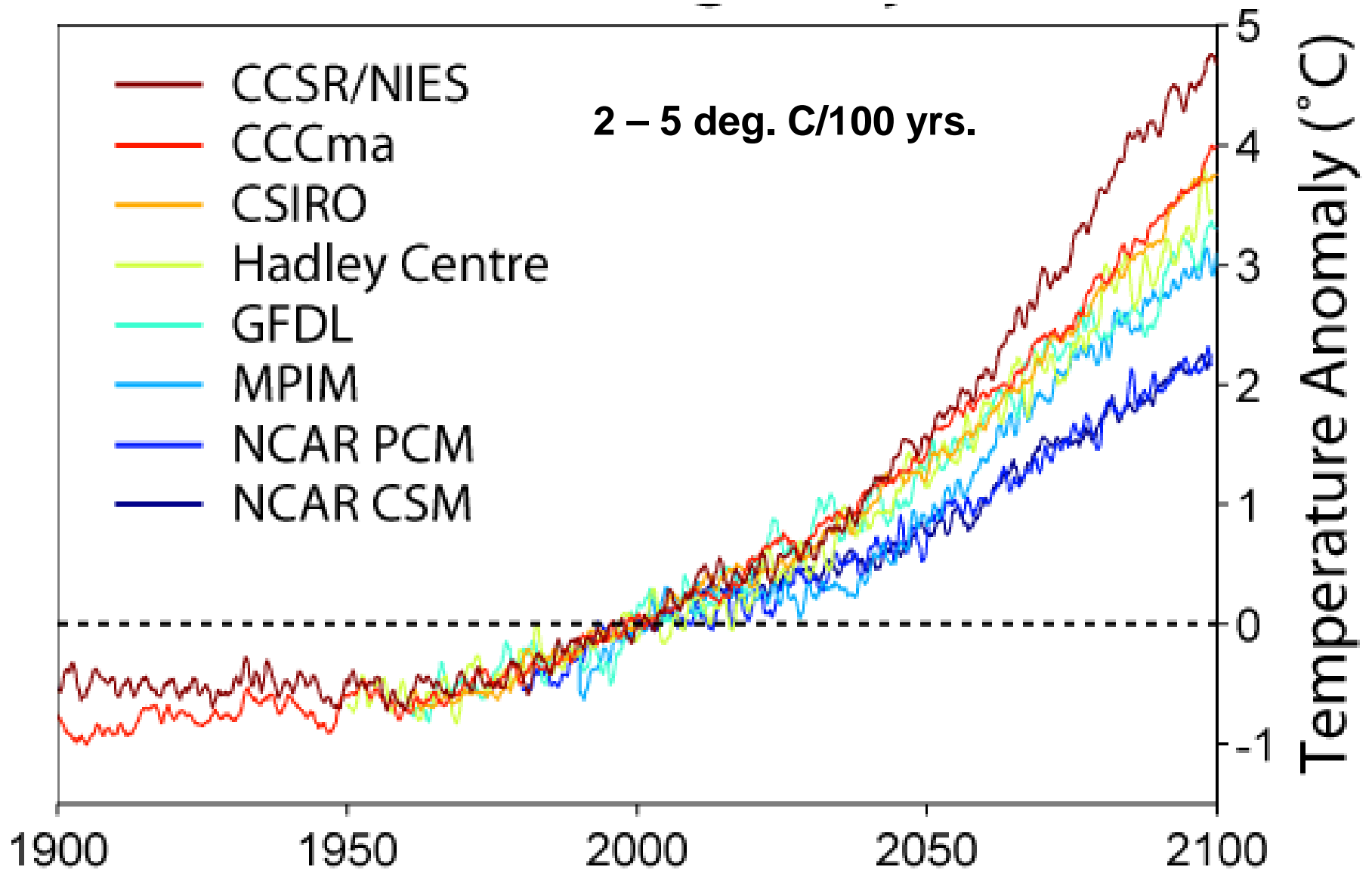


GLOBAL FOSSIL FUEL CO2 EMISSIONS

PER CAPITA CO2 EMISSION VS. POPULATION OF SELECTED COUNTRIES (2004)







GLOBAL WARMING PROJECTIONS BY VARIOUS RESEARCH AGENCIES



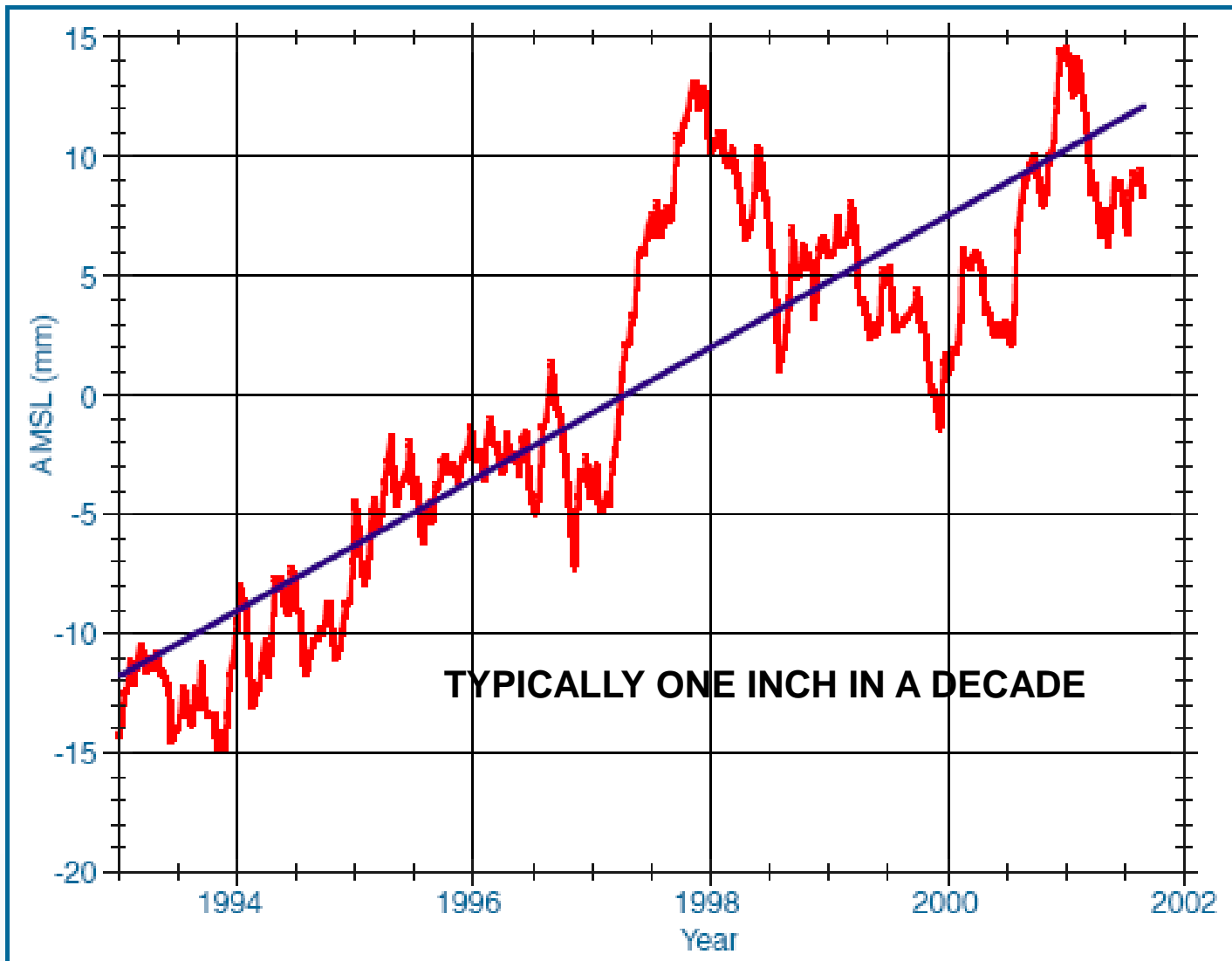
Data from ICE CORE STUDIES:

- **Chemical composition of the atmosphere**
- **Dust particle composition**
- **Air temperature**
- **Unusual events: volcanic eruptions,**
- **Nuclear radiation leaks.**

**ICE CORE STUDIES IN ANTERCTICA BY NSF
(KEEPS INVALUABLE ATMOSPHERIC RECORD)**

**MELTING OF ARCTIC OCEAN ICE
(SHRANK BY 500,000 SQ. MILES IN 2006 ALONE)**





SEA LEVEL RISE DUE TO GLOBAL WARMING
(TOPEX/Poseidon data- NASA/JPL Study of Ocean Surface Topography by altimetry data from Space Setellite) 18

Rise above
1990 sea level
(global average)

**100 MILLION PEOPLE LIVE WITHIN
3 FT. OF SEA LEVEL RISE**

3 feet

**Worst-case
scenario**
CO₂ at
971 ppm

2 -

**Best-case
scenario**
CO₂ at
478 ppm

1 -

3 in.

0 -

RIISING SEA LEVEL PROJECTIONS (GLOBAL AVERAGE)

2000

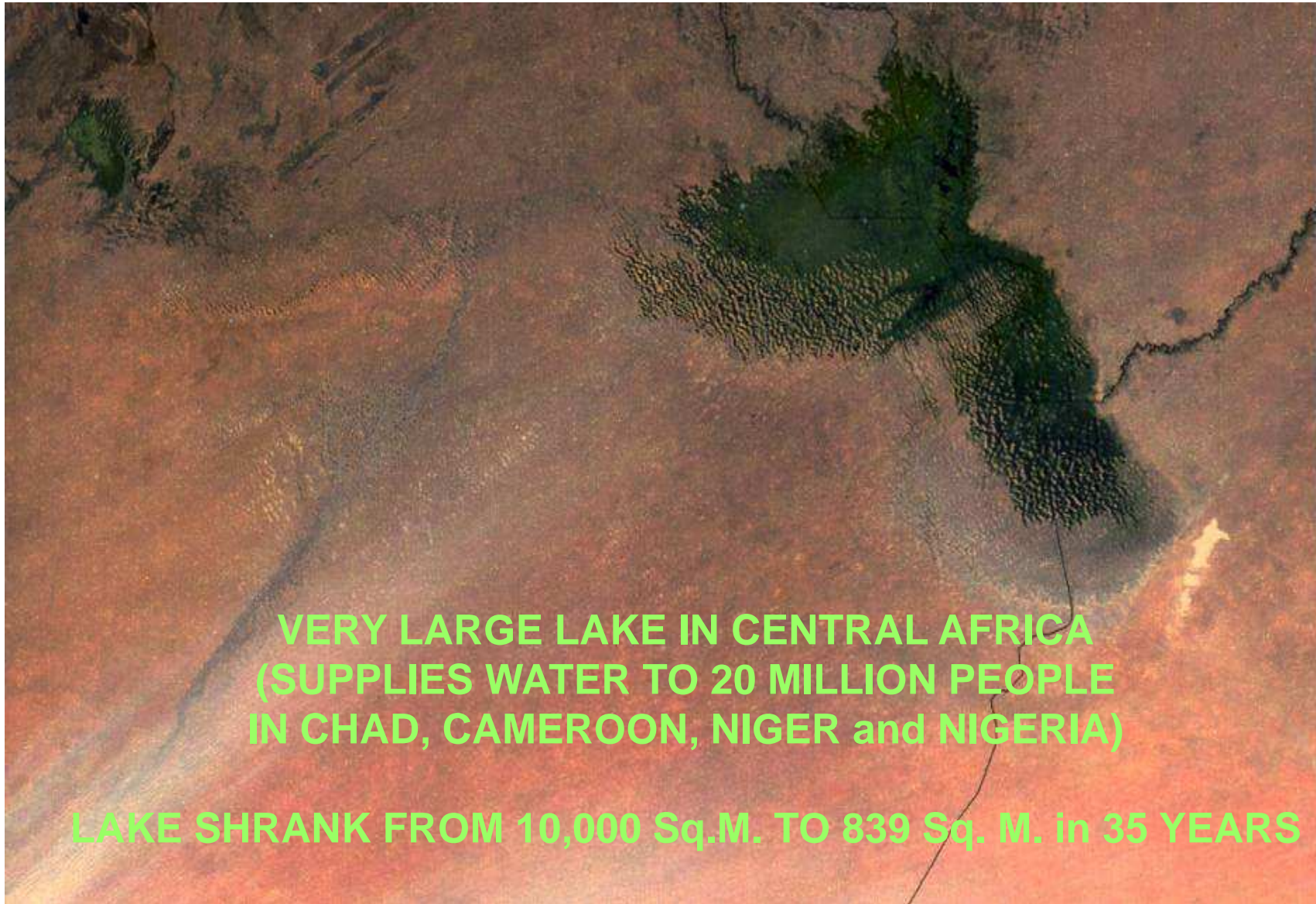
2020

2040

2060

2080

2100



**DROUGHTS IN LAKE CHAD IN CENTRAL AFRICA
(NASA SATELLITE PHOTO)**

SOME EXAMPLE SCENARIOS DUE TO GLOBAL WARMING *

- **50% OF BANGLADESH WILL BE UNDER WATER IN 300 YEARS DISPLACING 75 MILLION PEOPLE**
- **SEVERAL ISLAND NATIONS IN PACIFIC (Ex. TUVALU) WILL BE UNDER WATER WITHIN 100 YEARS. THEY HAVE PLEADED FOR HELP FROM UN**
- **INDIA'S AGRICULTURAL PRODUCTION WILL DECREASE 38% BY 2080s DUE TO DROUGHT – BUT CO₂ FERTILIZATION WILL OFFSET IT BY 9%**
- **IF ANTERCTICA AND GREENLAND ICE MELT, THE OCEAN LEVEL WILL RISE BY 200 FT.**
- **IF ALL ICE IN THE WORLD MELTS, THE OCEAN LEVEL WILL RISE BY 210 FT.**
- **ARCTIC REGIONS WILL BE VIRTUALLY FREE OF ICE BY 2070**
- **IF FOSSIL FUEL BURNING IS COMPLETELY STOPPED TODAY, OCEAN LEVEL WILL RISE BY 4.6 FT. IN NEXT 1000 YEARS**

* Estimate by UN-IPCC (Inter Governmental Panel of Climate Change)

KYOTO PROTOCOL FOR CLIMATE CHANGE

- The United Nations convened international meetings to discuss the challenges posed by global temperature and climate change.
- The **Kyoto Protocol**, a 1997 international agreement specifying action by nations to reduce greenhouse gas emissions, was developed at UN-sponsored meetings over many years.

- Many industrialized nations must **reduce by 2012** greenhouse gas emissions 5%-8% **below 1990 levels**.

European Union 8% reduction
(varies for each member country)

United States 7% reduction

Canada 6% reduction

Japan 6% reduction

Russia No further growth in emissions

Norway 1% increase permitted

**(USA has
refused to participate)**

- **Developing nations**, including China and India, **need not curb emissions during the 2008-2012 period**.

(PROTOCOL WENT INTO EFFECT FROM FEB. 2005)

KYOTO PROTOCOL AND CARBON EMISSION TRADING

- **THE PROTOCOL WAS EFFECTIVE FROM 2005 – NOW 183 MEMBER COUNTRIES COVERING MORE THAN 62% EMISSION**
- **EACH MEMBER COUNTRY HAS AN ASSIGNED QUOTA FOR EMISSION**
- **A COUNTRY WITH HIGHER EMISSION CAN CAP OR PURCHASE CREDITS FROM A COUNTRY WITH LOWER EMISSION (Ex. UK CAN BUY CREDITS FROM BRAZIL) – CAP AND TRADE POLICY**
- **WITHIN A COUNTRY, EACH INDUSTRY IS ASSIGNED A QUOTA FOR EMISSION**
- **AN INDUSTRY CAN CAP OR BUY/SELL CREDITS FROM ANOTHER TO MEET THE QUOTA**
- **IMPOSE CARBON TAX ON POLLUTERS – TAXING POLICY**
HEAVY TRUCK: \$1200, SUV: \$480, CAMRY: \$200
- **DIFFICULT TO MONITOR AND ENFORCE**
- **1990 USA CLEAN AIR ACT – ENFORCES SIMILAR SO₂ TRADING FOR ACID RAIN LEGISLATION – NOW \$3B INDUSTRY**

HOW TO SOLVE OR MITIGATE GLOBAL WARMING PROBLEMS?

- **PROMOTE ENERGY USAGE IN ELECTRICAL FORM**
- **CENTRALIZE FOSSIL FUEL ELECTRIC POWER GENERATION AND APPLY ADVANCED EMISSION CONTROL STRATEGY**
- **CUT DOWN OR ELIMINATE COAL- FIRED POWER GENERATION**
 - **ELSE, DEVELOP CLEAN COAL TECHNOLOGY (WITH CO₂ CAPTURE AND UNDERGROUND SEQUESTRATION)**
- **INCREASE NUCLEAR POWER**
- **PRESERVE RAIN FORESTS AND PROMOTE WIDESPREAD REFORESTATION**
- **CONTROL OF HUMAN AND ANIMAL POPULATION**
- **PROMOTE USAGE OF RENEWABLE ENERGY SOURCES**
 - **WIND, SOLAR, GEOTHERMAL, BIO FUELS, FUEL CELLS**
- **REPLACE ICE VEHICLES BY ELECTRIC/ HYBRID VEHICLES**
- **PROMOTE MASS TRANSPORTATION**
- **SAVE ENERGY BY MORE EFFICIENT GENERATION, TRANSMISSION, DISTRIBUTION AND UTILIZATION OF ELECTRICITY**

**POWER ELECTRONICS
INTENSIVE**

PREVENT ENERGY WASTE

SOME BENEFICIAL EFFECTS OF GLOBAL WARMING

- **CO₂ ABSORPTION BY PHOTOSYNTHESIS – HELPS NUTRITION OF AGRICULTURE AND PLANTS
(CARBON FERTILIZATION EFFECT)**
- **MELTING OF POLAR ICE CAPS OPENS NEW SHIPPING ROUTES
(EX: MELTING OF ICE HAS OPENED SHIPPING ROUTE IN ARCTIC OCEAN
REDUCING DISTANCE BETWEEN LONDON AND TOKYO BY 48% (13,000 MILES TO
8,100 MILES))**
- **25% OF WORLD'S OIL AND GAS RESERVES BELOW THE ARCTIC
ICE WILL BE AVAILABLE FOR EXPLORATION**
- **MELTING OF POLAR ICE WILL RECOVER NEW LANDS FOR
AGRICULTURE AND HABITATION
(EX: NORTHERN CANADA, RUSSIA AND GREENLAND WILL RECOVER NEW
LANDS)**
- **HEATING BILLS WILL BE REDUCED IN COLDER CLIMATES**

IMPORTANCE OF POWER ELECTRONICS

- **ELECTRICAL POWER CONVERSION AND CONTROL AT HIGH EFFICIENCY**
- **VERY IMPORTANT ELEMENT IN MODERN INDUSTRIAL AUTOMATION AND ENERGY PROCESSING SYSTEMS**
- **LOWER COST, SMALLER SIZE, HIGHER RELIABILITY AND LONGER LIFE OF MODERN SOLID STATE POWER ELECTRONIC APPARATUS ARE PROMOTING EXTENSIVE APPLICATIONS**
- **INCREASINGLY IMPORTANT ROLE OF POWER ELECTRONICS IN ENERGY SAVING**
- **GROWTH OF ENVIRONMENTALLY CLEAN RESOURCES OF ENERGY (WIND, PHOTOVOLTAIC AND FUEL CELLS) WHICH ARE POWER ELECTRONICS INTENSIVE**
- **GROWTH OF ELECTRIC AND HYBRID VEHICLES WHICH ARE POWER ELECTRONICS INTENSIVE**
- **VERY IMPORTANT ELEMENT FOR ELECTRICAL ENERGY STORAGE (BATTERY, SUPERCONDUCTING MAGNET, FLYWHEEL, ULTRACAPACITOR)**
- **IMPORTANT ELEMENT IN FUTURE SMART GRID**

HOW POWER ELECTRONICS CAN SAVE ENERGY?

- **CONTROL AND CONVERSION BY ELECTRONIC SWITCHING ARE HIGHLY EFFICIENT THAN BY M/G SETS AND RHEOSTATIC CONTROL**
- **NEARLY 60% OF GRID ENERGY IN USA IS CONSUMED IN MACHINE DRIVES – MAINLY FOR FLUID FLOW CONTROL BY PUMPS AND FANS**
- **TRADITIONALLY, FLUID FLOW IS CONTROLLED BY THROTTLE OR DAMPER OPENING WITH INDUCTION MOTOR RUNNING AT CONSTANT SPEED**
- **VARIABLE SPEED DRIVE WITH FULLY OPEN THROTTLE OR DAMPER CAN IMPROVE DRIVE EFFICIENCY BY UP TO 30% AT LIGHT LOAD**
- **LIGHT LOAD FLUX PROGRAMMING CONTROL CAN FURTHER IMPROVE DRIVE EFFICIENCY BY 20%**
- **VARIABLE SPEED LOAD-PROPORTIONAL AIR-CONDITIONER/HEAT PUMP CAN SAVE ENERGY UP TO 30%**
- **NEARLY 20% OF GRID ENERGY IS CONSUMED IN LIGHTING**
- **HIGH FREQUENCY FLUORESCENT LAMPS ARE 4-TIMES MORE EFFICIENT AND HAVE 10-TIMES LONGER LIFE THAN INCANDESCENT LAMPS**
- **EMERGING SOLID STATE LED LAMPS ARE 8-TIMES MORE EFFICIENT AND HAVE 50-TIMES LONGER LIFE THAN INCANDESCENT LAMPS**

WIND ENERGY SCENARIO

- **MOST ECONOMICAL, RENEWABLE, ENVIRONMENTALLY CLEAN AND SAFE “GREEN” ENERGY (~ 7 Cents/kWH)**
- **ENORMOUS WORLD RESOURCES – TAPPING ONLY 10% CAN SUPPLY ELECTRICITY NEEDS OF THE WHOLE WORLD**
- **COMPETITIVE COST WITH FOSSIL FUEL POWER (~ 6 Cents/kWH)**
- **RECENT TECHNOLOGY ADVANCES IN POWER ELECTRONICS, VARIABLE SPEED DRIVES AND VARIABLE SPEED WIND TURBINES**
- **CURRENTLY, USA IS THE WORLD LEADER IN INSTALLED CAPACITY (35 GW) (CLOSE TO GERMANY) AND TOTAL ENERGY GENERATION**
- **CURRENTLY, 2.0% WIND ENERGY IN USA – MAY INCREASE DRAMATICALLY TO 20% BY 2030**
- **CURRENTLY, 20% WIND ENERGY IN DENMARK – EXPECTED TO INCREASE TO 40% BY 2030**
- **PROBLEM OF STATISTICAL AVAILABILITY – NEEDS BACK-UP POWER OR STORAGE**
- **KEY ENERGY SOURCE FOR FUTURE HYDROGEN ECONOMY**

PHOTOVOLTAIC ENERGY SCENARIO

- **SAFE, RELIABLE, STATIC AND ENVIRONMENTALLY CLEAN RENEWABLE “GREEN” POWER**
- **DOES NOT REQUIRE REPAIR AND MAINTENANCE**
- **PV PANELS ARE EXPENSIVE – PRICE IS FALLING
(CURRENTLY AROUND \$3.00/W, 20 Cents/kWH)**

**APPLICATIONS: SPACE POWER
ROOF TOP INSTALLATIONS
OFF-GRID REMOTE APPLICATIONS**

- **CURRENTLY, ONE-THIRD OF WORLD POPULATION LIVE OFF-GRID. WIND AND PV ARE VERY IMPORTANT TO THEM**
- **PROBLEM OF SPORADIC AVAILABILITY
– REQUIRES BACK-UP POWER OR ENERGY STORAGE**
- **CURRENT TERRESTRIAL INSTALLATION (12.8 GW)
JAPAN – 46%
USA – 28%
EUROPE – 22%**
- **TREMENDOUS EMPHASIS ON TECHNOLOGY ADVANCEMENT FOR COST REDUCTION**

ELECTRIC AND HYBRID ELECTRIC VEHICLE SCENARIO

- **VERY PROMISING IN NEAR FUTURE DUE TO HIGHER OIL PRICE, ENERGY SAVING AND REDUCED ENVIRONMENTAL POLLUTION - BUT MORE EXPENSIVE**
- **LIMITATION OF BATTERY TECHNOLOGY – COST, CYCLE LIFE, SIZE, WEIGHT, AND FAST CHARGING PROBLEMS**
- **HIGH ENERGY DENSITY LITHIUM-ION BATTERY IS AROUND THE CORNER – BUT EXPENSIVE**
- **PURE EV RANGE IS LIMITED, BUT HEV HAS NO SUCH LIMITATION**
- **PLUG-IN HYBRID WITH LITHIUM-ION BATTERY IS AROUND THE CORNER –YET EXPENSIVE**
- **POWER DEVICES IN HEV – IC ENGINE, DIESEL ENGINE, MICRO GAS TURBINE, FUEL CELL**
- **STORAGE DEVICES IN EV/HEV – BATTERY, ULTRA CAPACITOR, FLYWHEELS**

CONCLUSION AND FUTURE SCENARIO

- **GLOBAL ENERGY CONSUMPTION IS INCREASING DRAMATICALLY – DUE TO INCREASING WORLD POPULATION AND SEARCH FOR BETTER LIVING STANDARD**
- **DWINDLING RESOURCES OF FOSSIL AND NUCLEAR FUELS**
- **SHORTAGE OF FOSSIL FUELS AND ENVIRONMENTAL REGULATIONS WILL DRAMATICALLY INCREASE COST OF ENERGY – PROMOTING ENERGY SAVING BY POWER ELECTRONICS**
- **INCREASING EMPHASIS ON “GREEN” RENEWABLE ENERGY SOURCES**
- **GLOBAL WARMING WILL HAVE DIRE CONSEQUENCES IN FUTURE
– POOR NATIONS NEAR EQUATOR (AFRICA, INDIA ETC.) WILL SUFFER MOST, WHEREAS SOME AFFLUENT NATIONS (CANADA, RUSSIA ETC.) WILL HAVE SOME GAIN. WILL CAUSE SERIOUS UNREST IN THE WORLD**
- **POWER ELECTRONICS WILL PLAY VERY IMPORTANT ROLE IN ENERGY SAVING. CLEAN ENERGY GENERATION AND EFFICIENT ENERGY UTILIZATION – EVENTUALLY KEY ELEMENT IN ENERGY POLICY OF NATIONS**
- **RECENT STUDY IN STANFORD UNIVERSITY INDICATES THAT RENEWABLE ENERGY SOURCES ALONE WITH SOME STORAGE CAN MEET ALL OF OUR ENERGY NEEDS IN FUTURE**

THANK YOU