Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

Global Warming Initiative

R&D Seminar
July 25, 2008

Presentation Overview

- General Information, Definitions
- Paleoclimate
- IPCC Perspective
- NIPCC Perspective
- Energy Outlook
- Carbon Regulation (?)
- Global Warming Initiative
- Carbon/ Energy Footprint (2005 Actual)
- Strategy/Discussion

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Acknowledgements

MWRDGC Global Warming Initiative

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Contributing Colleagues

- John Norton, MWH
- Tony Quintanilla
- Guonglong Tian

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Greenhouse Effect

- The Sun heats the Earth's surface and atmosphere.
- Half of the Sun's heat is filtered, absorbed, or removed by other mechanisms in the atmosphere
- Some gases temporarily absorb infrared light of specific wavelengths
- This re-radiated energy is absorbed by the earth and consequently heats the surface and surrounding air
- This phenomenon is known as the greenhouse effect, and the gases responsible are known as greenhouse gases (GHGs)

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Definitions

- **Global Warming**
  - ***Increase in average temp of earth's atmosphere***
  - ***Generally used in context of human influence***
- **Climate Change**
  - ***Significant change temp, precip, wind, > decade***
  - ***Natural factors: sun's intensity, earth's orbit***
  - ***Natural fluctuations in climate system (ie, ocean circulation)***
  - ***Human activity that changes atmospheric composition***

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“Now overwhelming scientific consensus that fossil fuels are causing serious climate change”

(*Science, December 2004*)

“The climate is changing at an unnerving pace. Glaciers are retreating, ice shelves are fracturing, sea level is rising, permafrost is melting....How can we not cover the biggest geography story of the century?”

(*National Geographic, September 2004 issue, which devoted 74 pages to the signs of climate change*)

"WE ARE ANTICIPATING ANOTHER 8-12 INCHES OF GLOBAL WARMING TODAY."

Paleoclimatology

- Study of past climates
- Multidiscipline inquiry: history, anthropology, archaeology, chemistry, physics, geology, atmospheric, ocean sciences
- Past climate: Proxy indicators
  - *Isotopic Geochemical Studies: The study of rock isotopic ratios, ice core bubbles, deep sea sediments, etc.*
  - *Dendochronology: the study of tree rings*
  - *Pollen Distribution: the study of plant types and prevalence from pollen found in sediments, ice, rocks, etc.*
  - *Lake Varves: (like dendochronology, with lake sediments)*
  - *Coral Bed Rings*
  - *Fossils: Studies of geological settings, etc.*
  - *Historical documents, paintings, evidence of civilizations, etc.*

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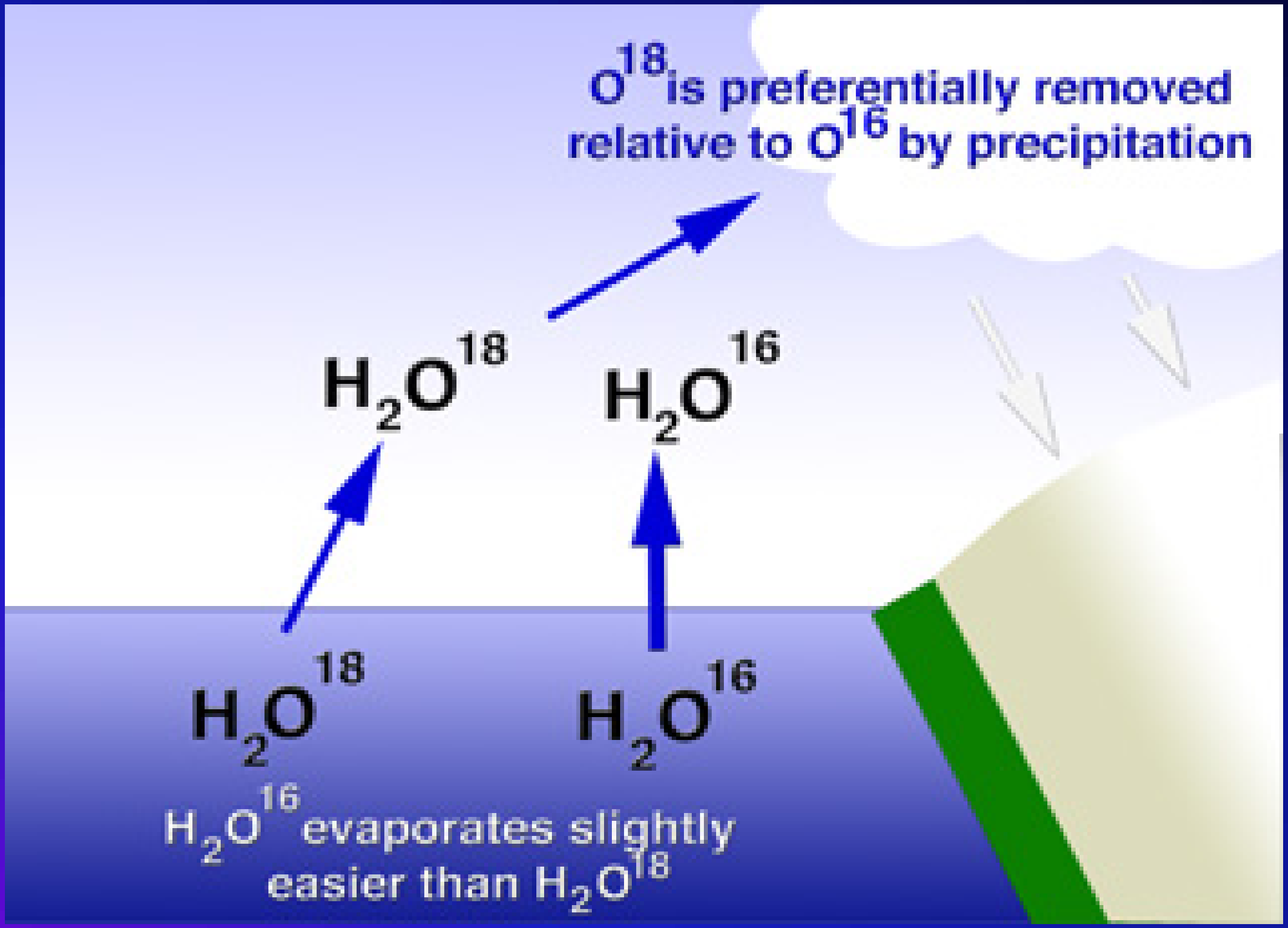

http://www.globalchange.umich.edu/kling/paleoclimate

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Climate Change

- Changes in solar output
- Changes in Earth's orbit
- Changes in the distribution of continents
- Changes in the concentration of Greenhouse Gases in the atmosphere

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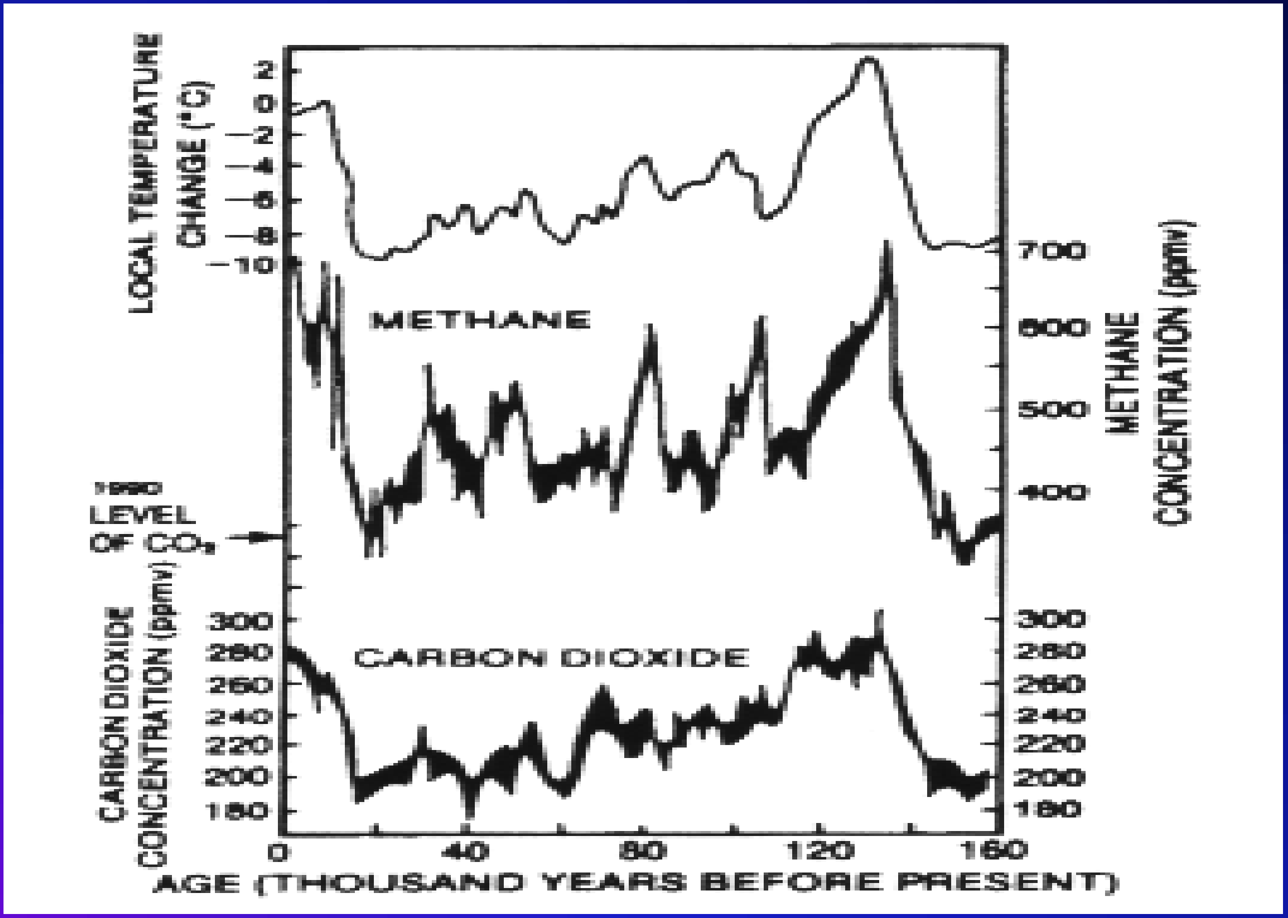
Past Temperature Correlation with Atmospheric Methane and Carbon Dioxide



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Paleoclimate – 5 Billion Years/ 15 Billion Year Universe

- First 500 million years: H_2, H_2O, CH_4
- 400 billion years ago: oceans formed
- 2.5 billion years ago: archaea and cyanobacteria
- 2.3 billion years ago: photosynthesis creates first oxygen in atmosphere
- 900 million years ago: increased photosynthesis (rock record)
- 600 million years ago: first marine organisms & ozone layer
- 400 million years ago: first land plants
- ~ 3.2 million years ago: Lucy (*A. afarensis)*
- ~ 250,000 homo sapiens

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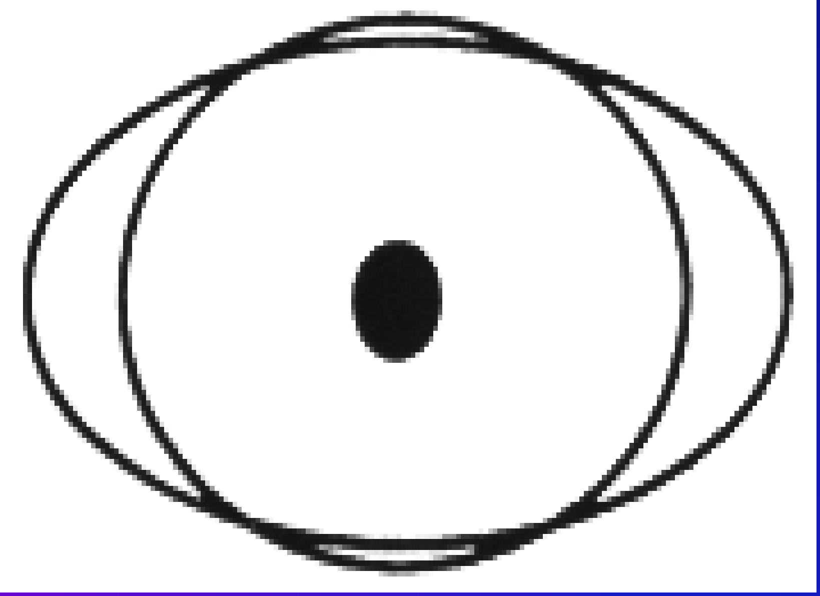
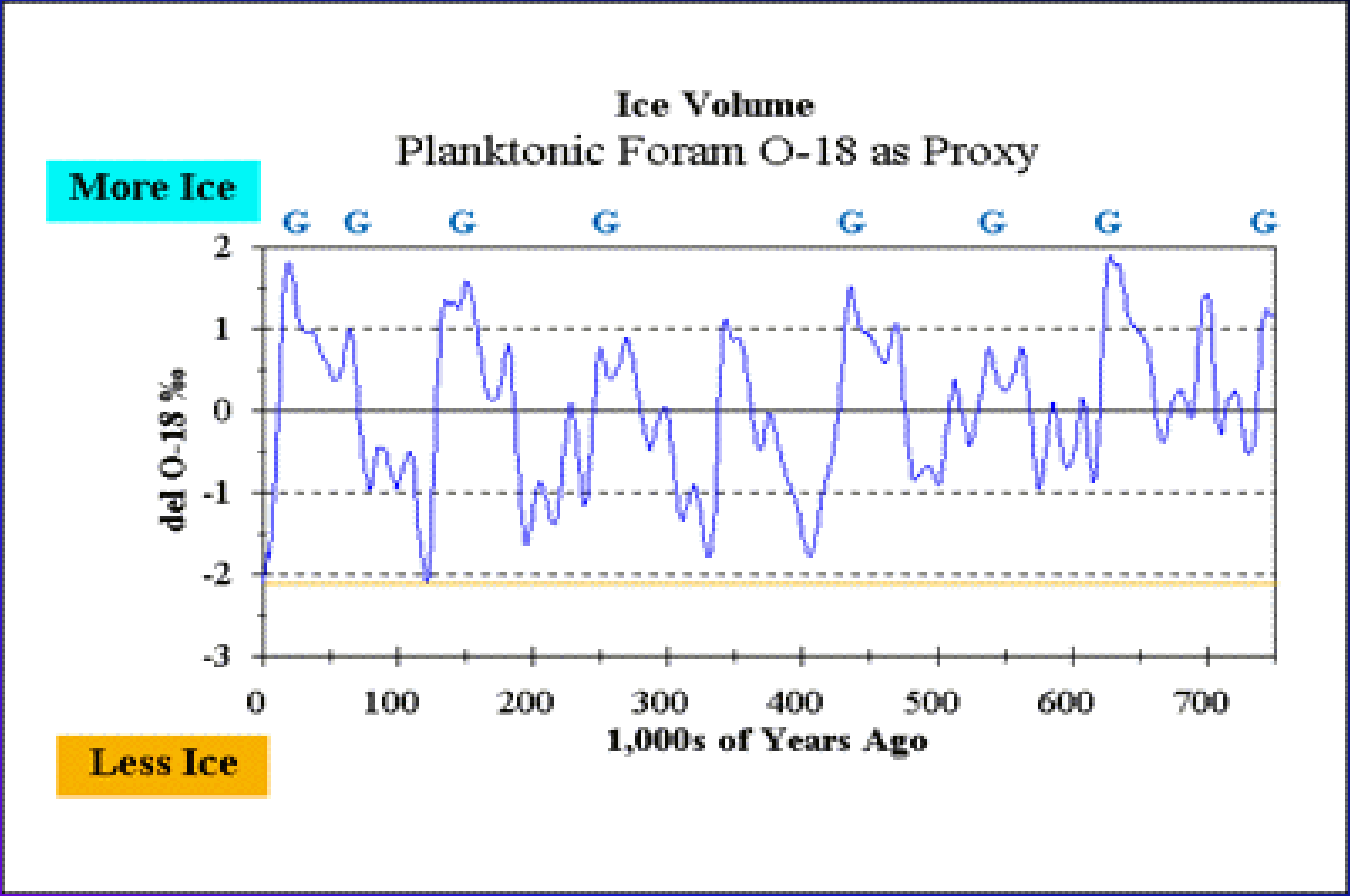
Milankovitch Cycles



- Serbian civil engineer/ geophysicist
- Ice Ages ~ 100,000 year cycle
- Theory proposed in 1924
- Published in English 1942
- Doubted in 1950's
- Supported in 1970's with deep ocean core samples



Ice Volume
Planktonic Foram O-18 as Proxy
More Ice
Less Ice
G
G
G
G
G
G
G
G
2
1
0
-1
-2
-3
del O-18 ‰
0
100
200
300
400
500
600
700
1,000s of Years Ago

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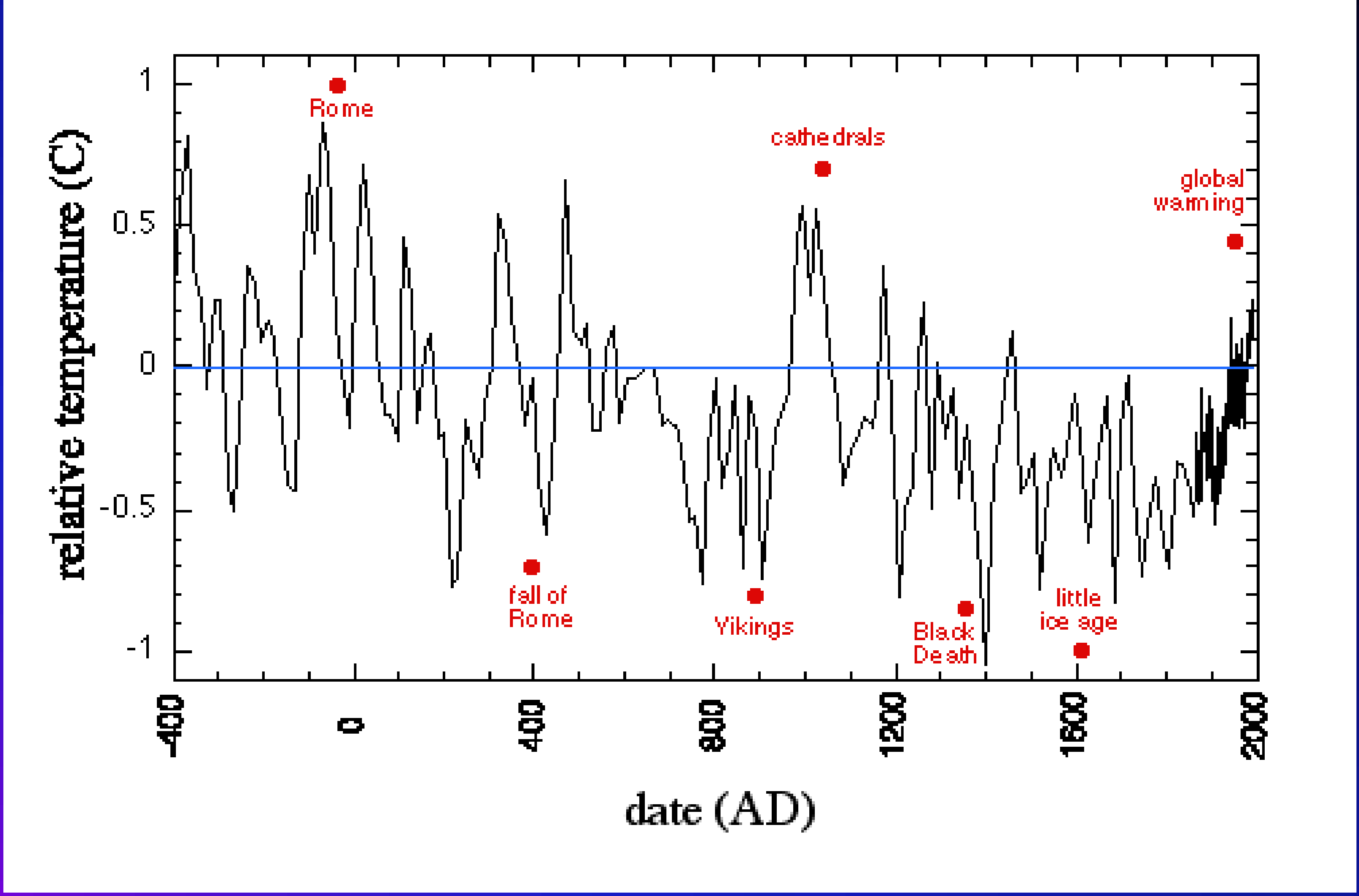

http://muller.lbl.gov/pages/IceAgeBook/history_of_climate.html

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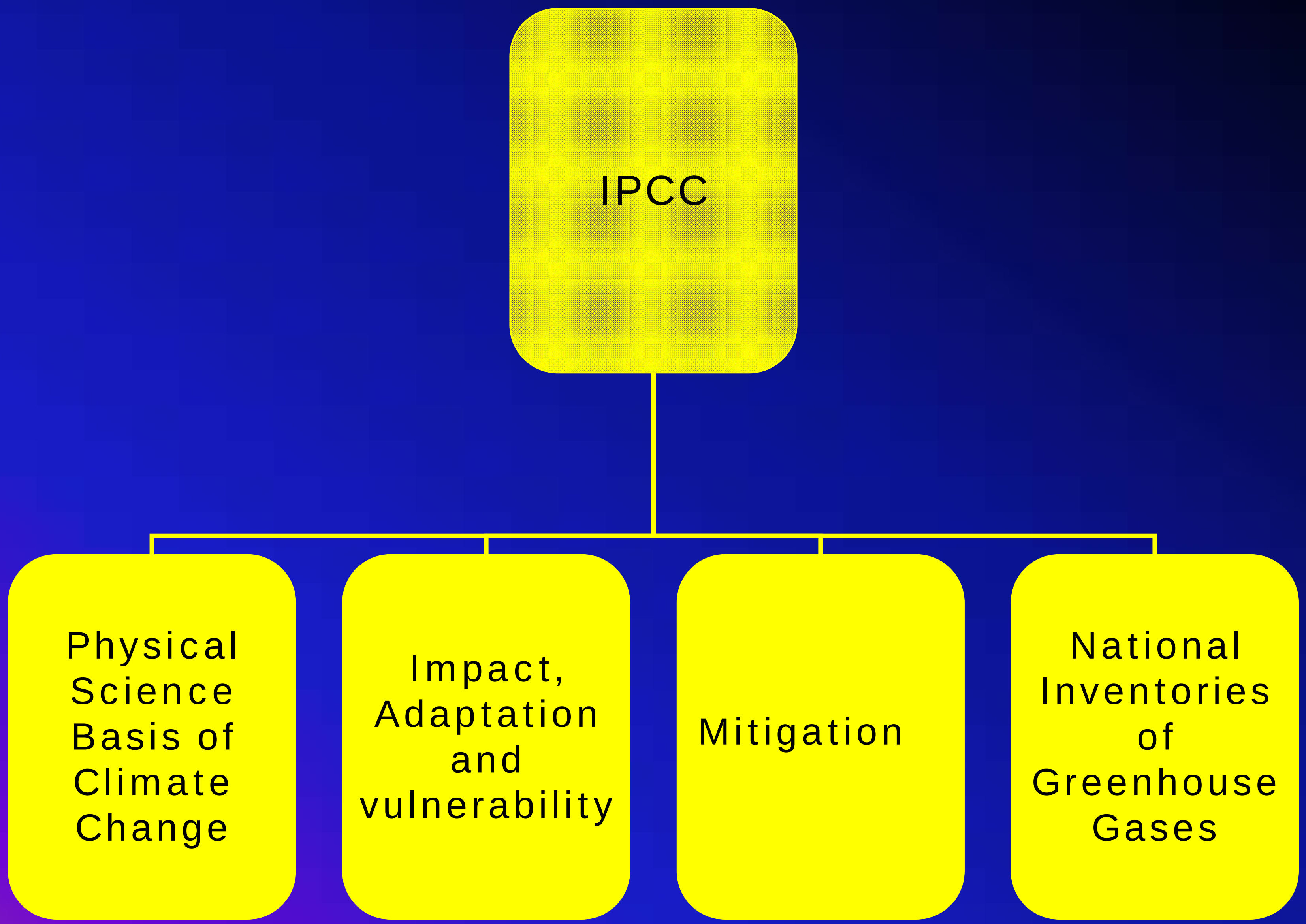
Paleoclimate Summary

- The Earth's climate has changed dramatically in the past, apparently in response to natural changes in orbital characteristics and topography (plate tectonics).
- We are able to deduce past climates through multiple techniques but much of the progress in resolving Cenozoic (recent) climate change has resulted from oxygen and carbon isotope records.
- A paleoclimate record has been developed using different techniques, stretching back over 2 billion years. The Earth was warmer than at present for most of this time, punctuated by infrequent Ice Ages.
- The Great Ice Ages may have been caused by processes associated with continental drift and greenhouse warming.
- The interglacial periods are related to orbital changes described by the Milankovitch cycles, among other factors.

Intergovernmental Panel on Climate Change

- **Convened in 1988 by**
  - ***United Nations Environmental Programme***
  - ***World Meteorological Organization***
- **Advisory Role (no research/ data review)**
- **First IPCC Assessment Report – 1990**
- **Rio de Janeiro Summit – 1992**
- **Second IPCC Assessment Report – 1995**
- **Kyoto Protocol – 1997**
- **Third IPCC Assessment Report – 2001**
- **Fourth IPCC Assessment Report - 2007**


IPCC
Physical Science Basis of Climate Change
Impact, Adaptation and vulnerability
Mitigation
National Inventories of Greenhouse Gases

Climate change
is unequivocal

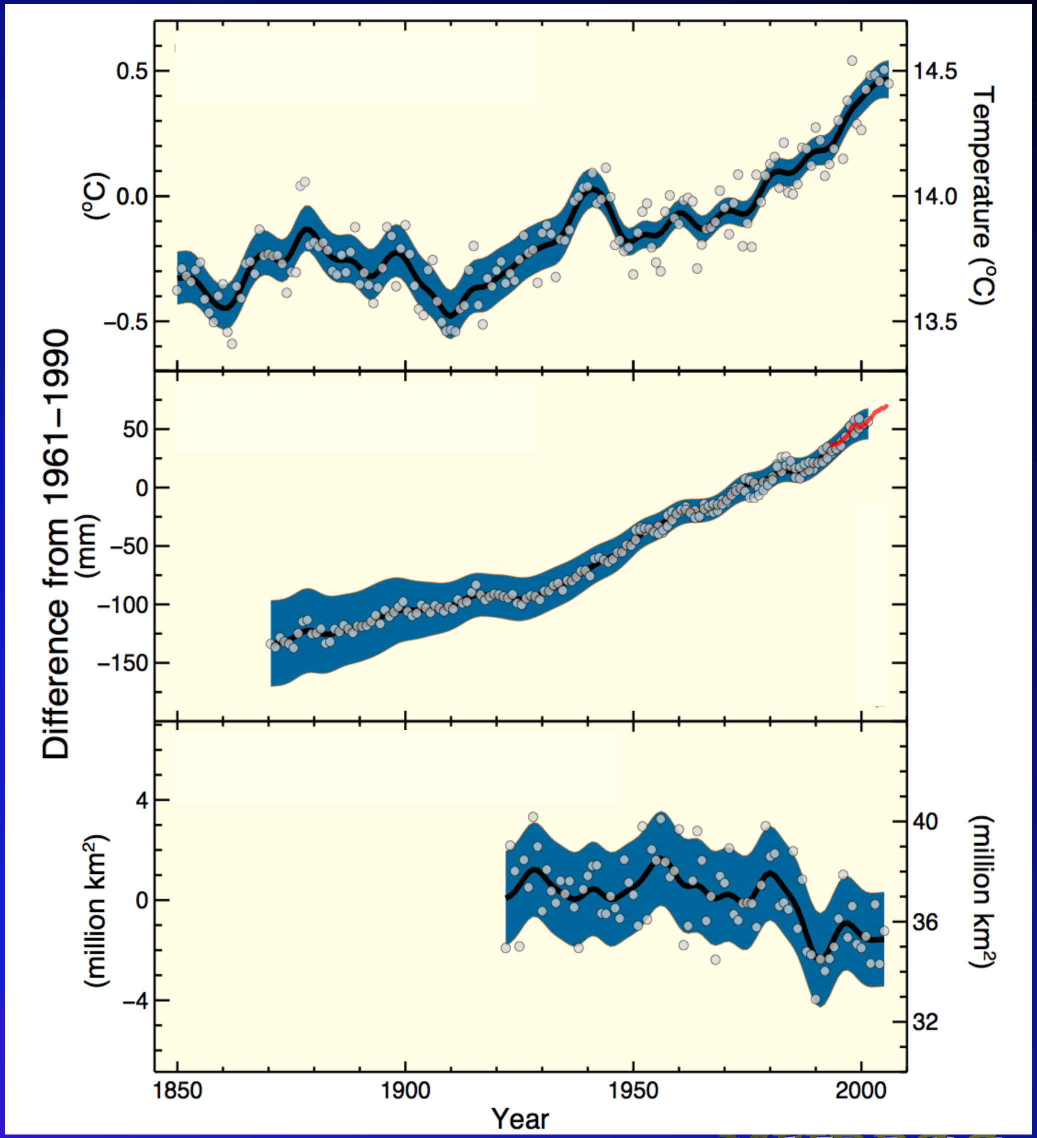
IPCC, 2008

Observed changes

Global average temperature

Global average sea level

Northern hemisphere snow cover



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Heat waves have become more frequent over most land areas

-Heat wave in Europe, 2003: 35 000 deaths

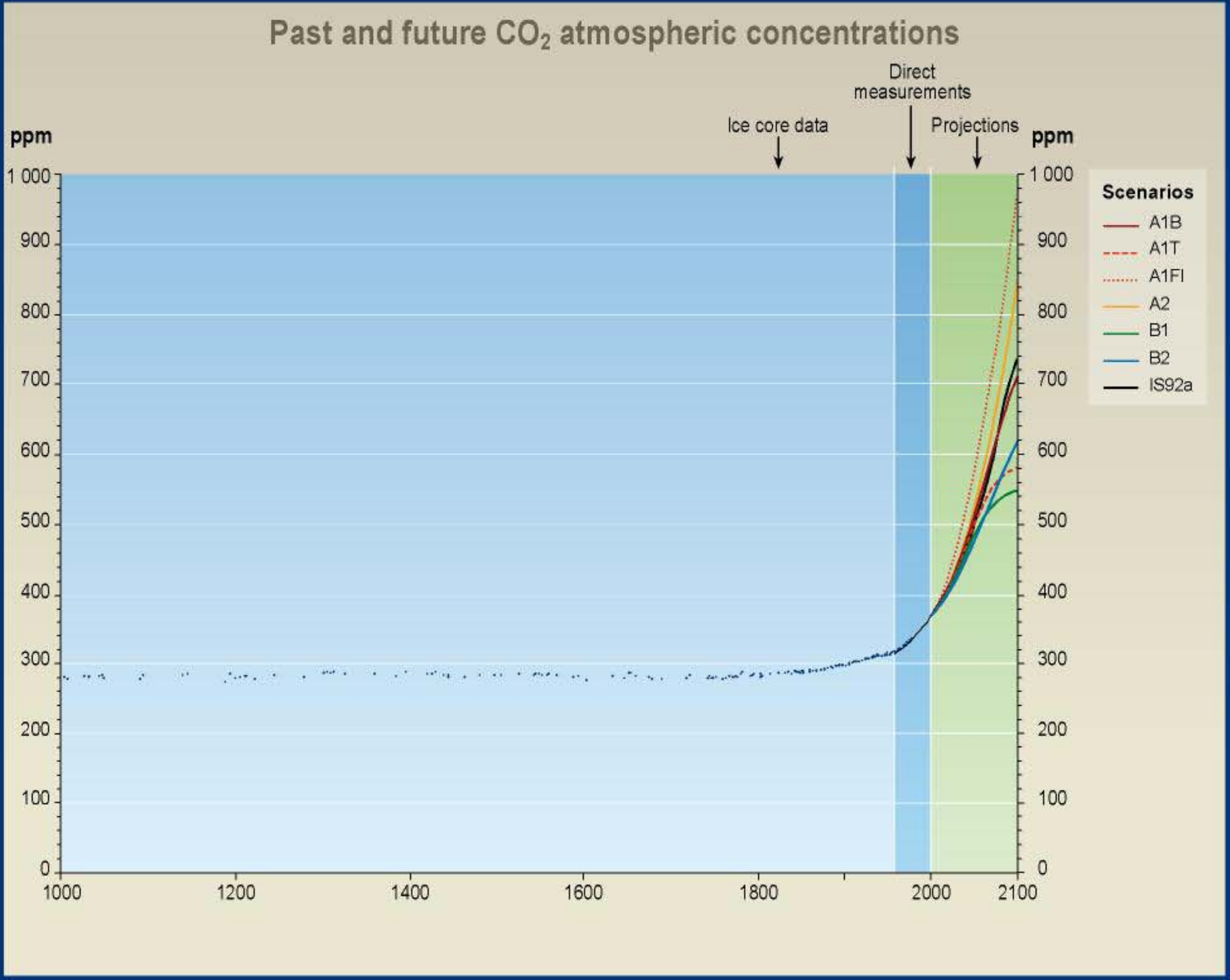
-IPCC, 2008

Intense tropical cyclone activity has increased in the North Atlantic since about 1970

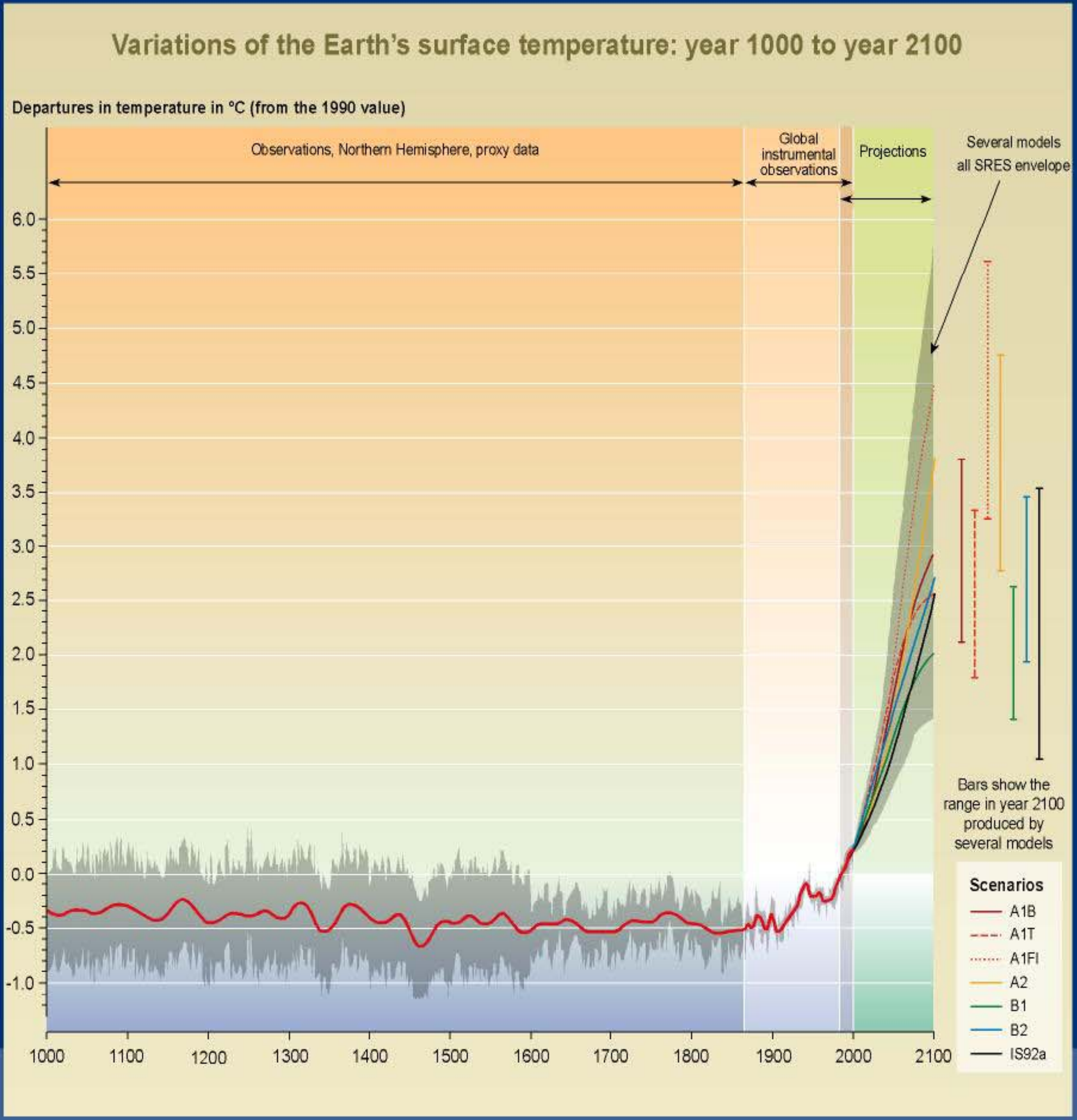
- Hurricane Ivan: 2004

- Hurricanes Katrina, Rita and Wilma: 2005

IPCC, 2008

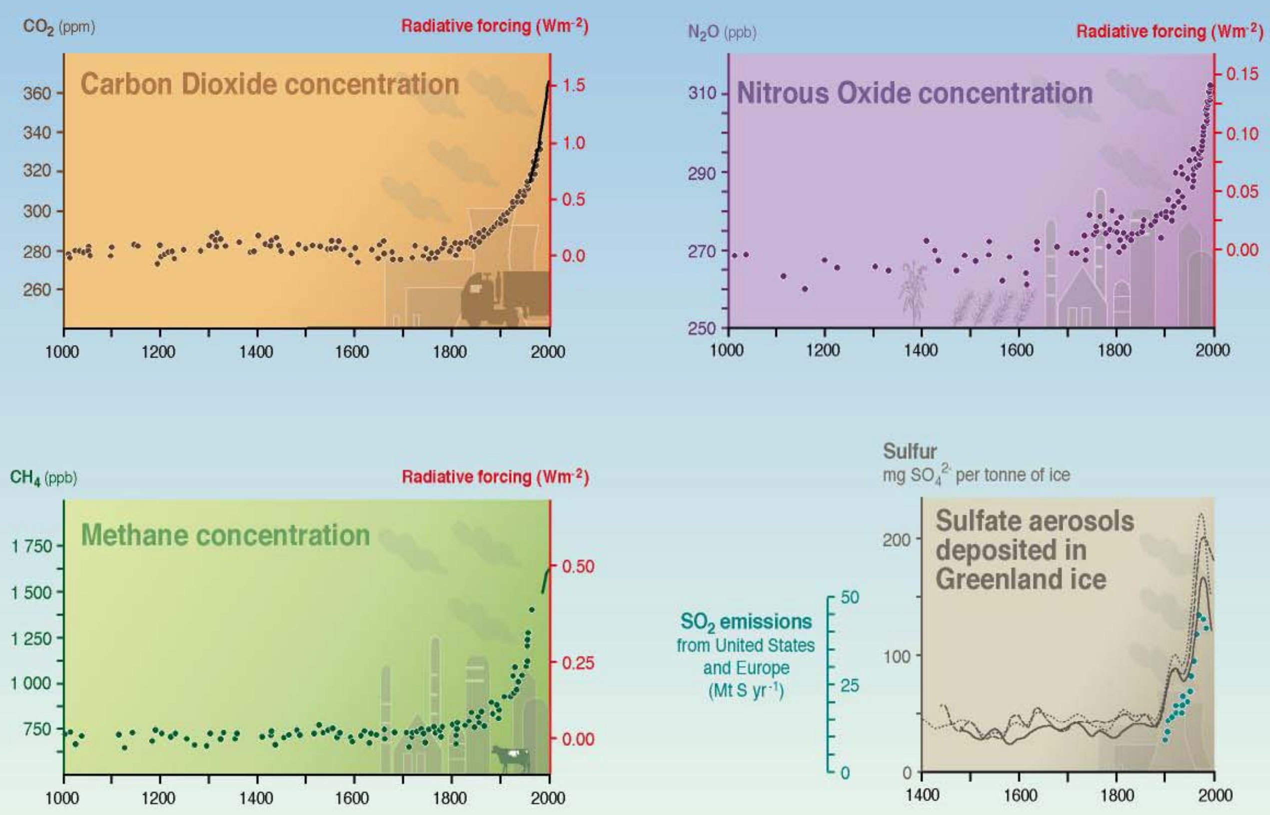


SYR - FIGURE 9-1a

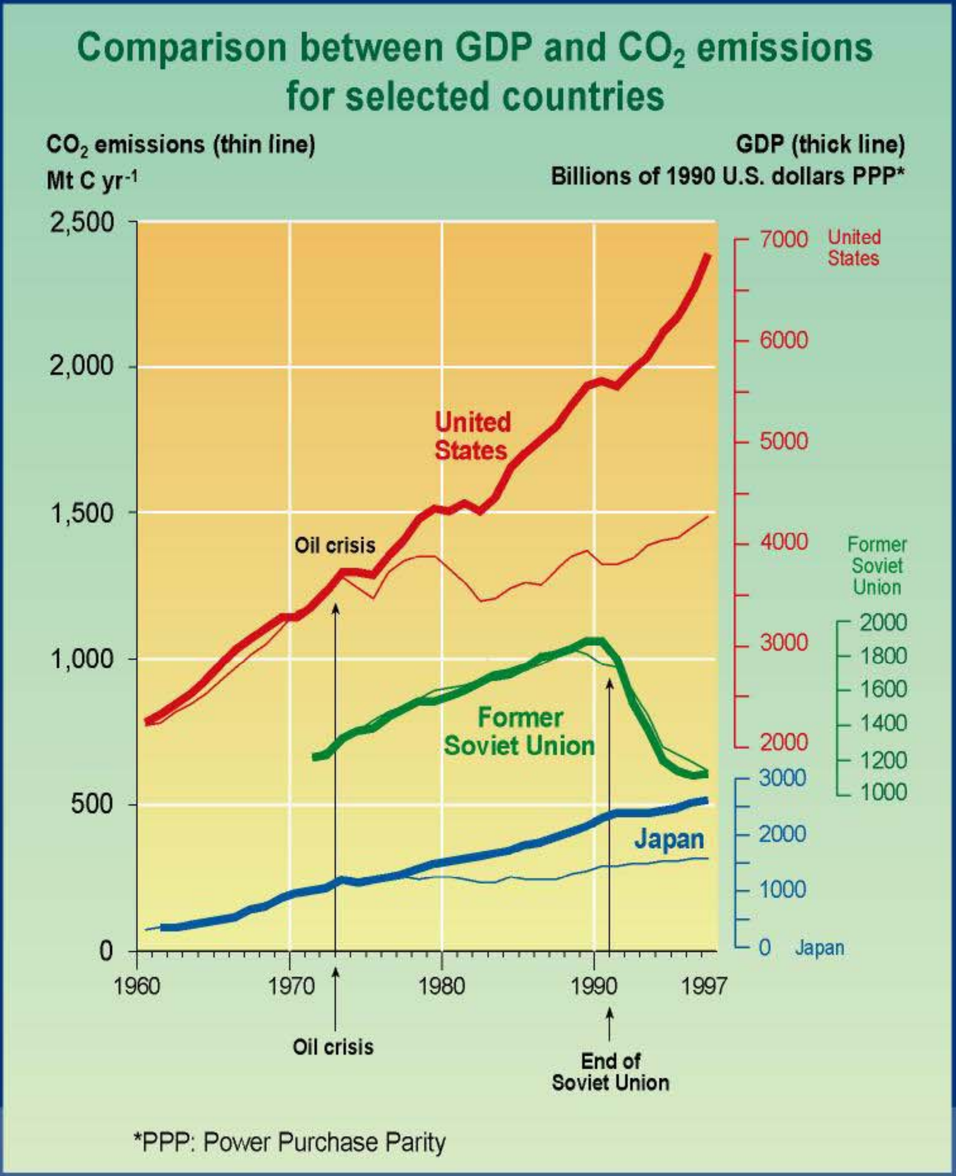


SYR - FIGURE 9-1b

Indicators of the human influence on the atmosphere during the Industrial era



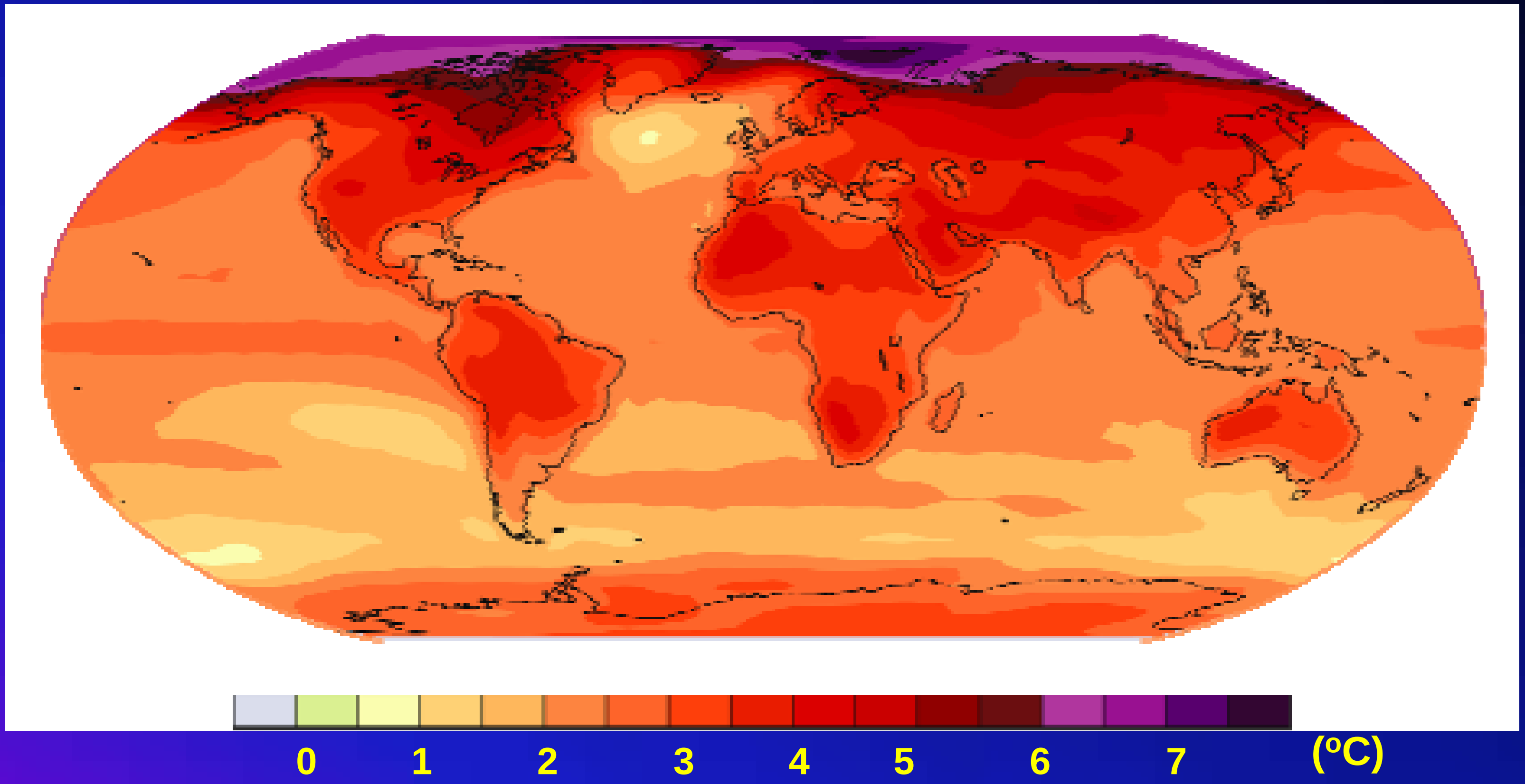
SYR - FIGURE 2-1
WG1 FIGURE SPM-2



SYR - FIGURE 5-6

Projected surface temperature changes

(2090-2099 relative to 1980-1999)



Continued emissions would lead to further warming of 1.8ºC to 4ºC over the 21st century and induce many changes that would be larger than those observed during the 20th century

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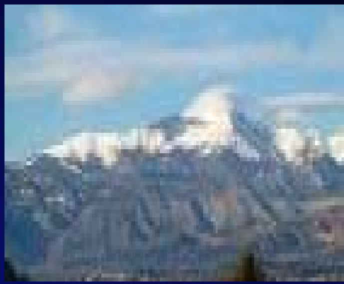
Expected impacts on North America

Warming in western **mountains** is projected to cause decreased snowpack and reduced summer flows, exacerbating competition for over-allocated water resources



Increased number, intensity and duration of **heatwaves** will have potential for adverse health impacts

Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution

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The urgent need for mitigation of greenhouse gases

Available tools for business

Voluntary agreements and actions

- Help increase profitability or protect competitive position in the event of future regulatory mandates

Management tools

- GHG Inventory
- Management Systems
- Benchmarking

Technology development & transfer

- Clean Development Mechanism
- Joint Implementation
- Research & development

Carbon markets

Growing price of carbon on **EU carbon market** has encouraged businesses to consider new opportunities, driving Europe towards technological leadership

There are clear signs that **other countries**, including the USA, will follow the EU's lead in the coming years

For stabilization at levels between 450 and 550 ppm CO_2-eq, global carbon prices of up to 100 US$/t$CO_2$-eq **need to be reached by around 2030**

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Trends in energy investments

Sustainable energy investment was $70.9 billion in 2006, an increase of 43% over 2005

- Wind sector attracted the most investment (38% of the total) followed by biofuels (26%) and solar (16%)

Global renewable energy capacity grew at rates of 15-30% annually for many technologies in 2002-2006

Demand for global energy service has grown by 50% since 1980 and is expected to grow another 50% by 2030

➡ **There is a powerful signal to the arrival of a profitable market for low-carbon products**

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Non-governmental International Panel on Climate Change (NIPCC)

2008 International Conference on Climate Change
New York, New York

Reasons:

- **Climate models: curve-fitting**
- **Agree that climate is warming**
- **Humans responsible for 3.5 % CO_2**
- **Solar radiation responsible for warming**
- **Anthropogenic argument: politically motivated alarmism**

White Spruce 100 km north of current tree line - Radiocarbon Date 4940±170:

Courtesy of Professor Ritchie

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CO_2 Mitigation is Not Needed

Cap & Trade: pointless, political, expensive

Ethanol: ineffective and wasteful; subsidized

Wind, Solar: marginally useful, with subsidies

Carbon Capture: not needed and very costly.

Instead:

Generate Electric power from secure and low-cost coal/nuclear: phase out natural gas and use as transportation fuel, feedstock, etc

S. Fred Singer, Ph.D.

The NIPCC Report: Nature, not Human Activity, Rules the Climate

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Present-Day Composition

- 78% Nitrogen – dilutes oxygen, protein
- 21% Oxygen – respiration, combustion
- 0.9% Argon – light bulbs
- 0.3% Carbon Dioxide – plants respiration, planet warming
- 0 – 4 % Water Vapor – essential for life, also warms planet
- Trace gases - neon, helium, krypton, xenon

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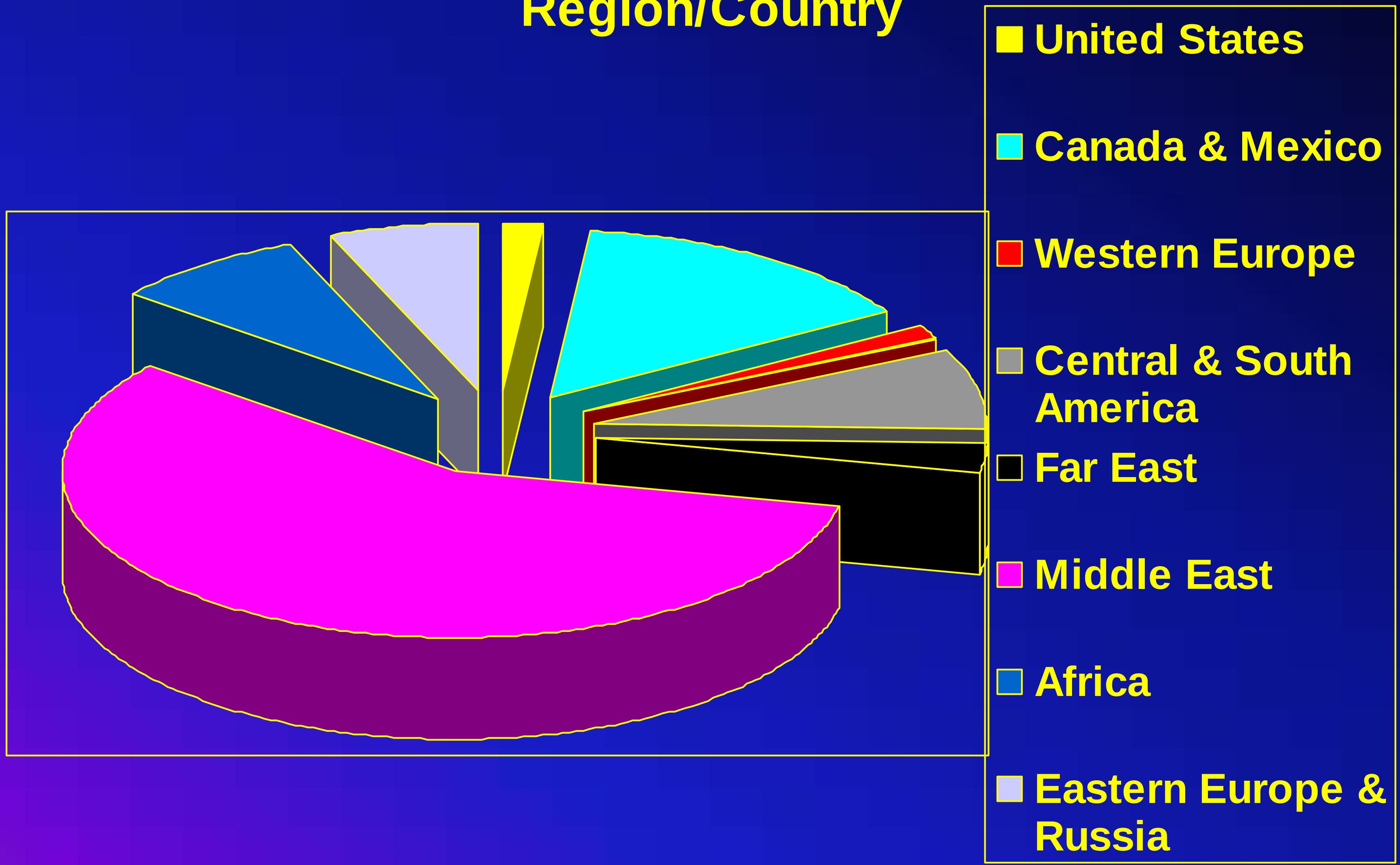
Energy Outlook

- Fossil Fuels are finite
- Combustion: particulate emissions
- Coal: mercury, SOx, NOx
- Air Pollution
  - *Health Impacts*
  - *Quality of Life*
- Transportation: Oil
- Unprecedented transfer of wealth
- Social/ political implications

Portion of Proven Oil Reserves by Region/Country



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Worldwide Energy Outlook

Oil

Proven Reserves (billion barrels):

1,201 (*BP Stat Rev.*) 1,317 (*Oil, Gas Jour.*)

Consumption: 30,660 million barrels/year

~ 40 years (at current rate of consumption)

Natural Gas

Proven Reserves (trillion ft^3)

6,183 (Energy Information Agency, DOE)

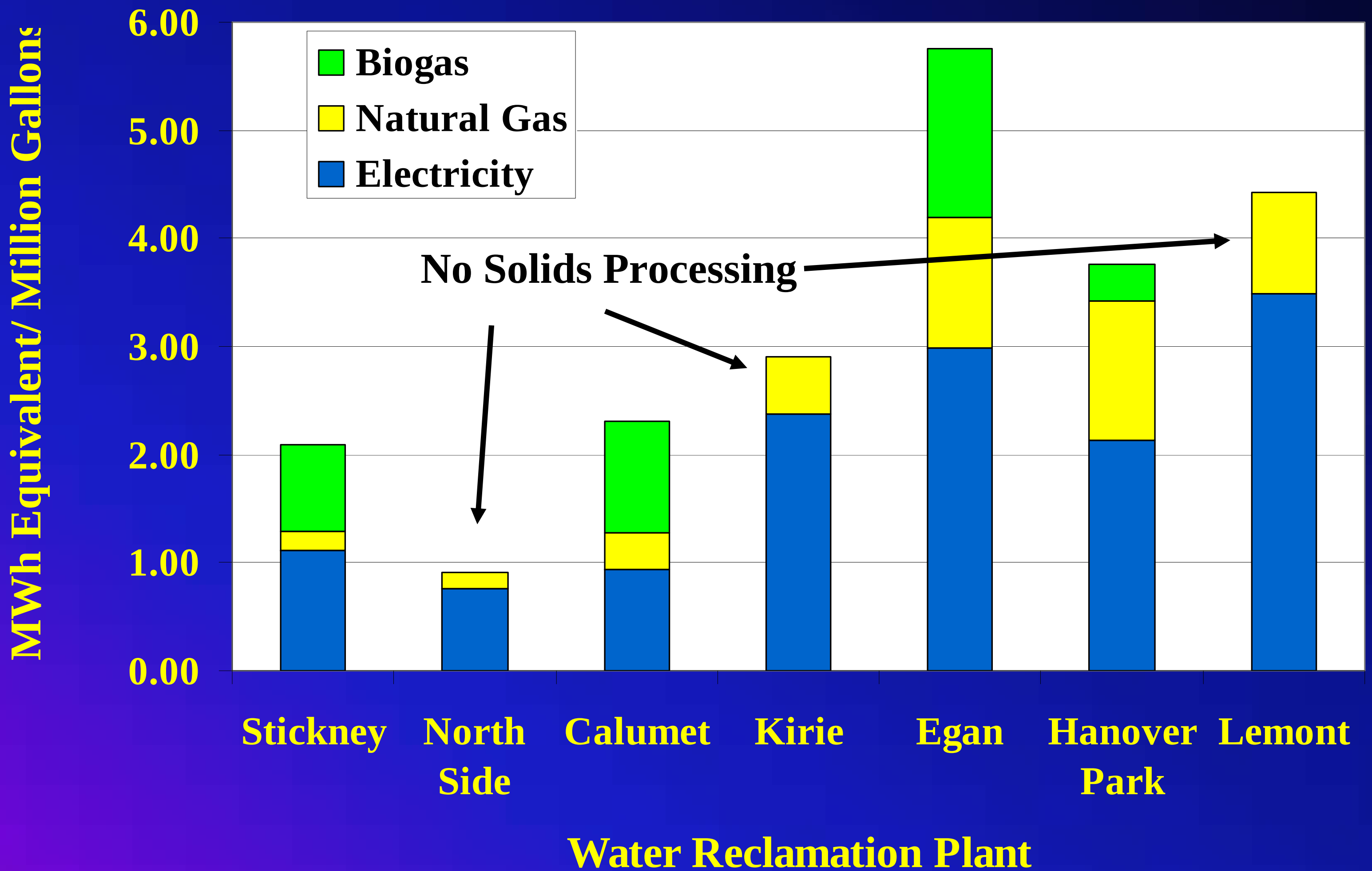
Consumption: 100 trillion ft^3, 2005

~ 60 years (at current rate of consumption)

Energy Use at MWRDGC

- Energy Used in Plant Operations
- Energy Generated at Plant Operations
- Energy Used to Manage Waterways
- Energy Generated by Hydropower

Energy Footprint at Water Reclamation Plants - 2005 Actual



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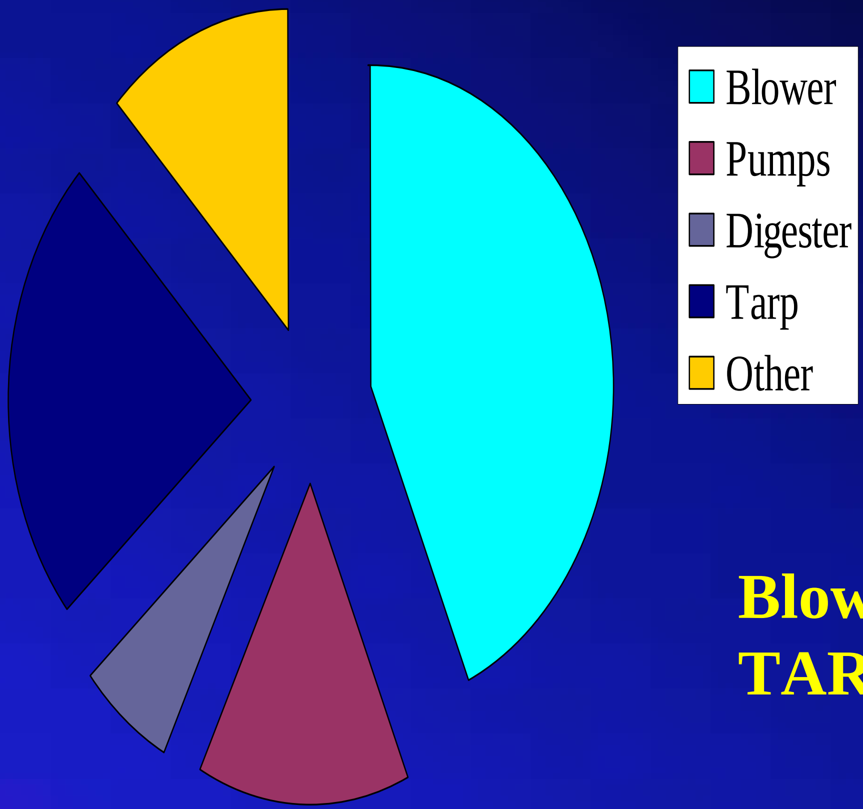
Calumet WRP Operations Electricity Demand



Blowers ~ 45%
TARP ~ 25%

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Lockport Powerhouse: Hydropower

- Located: Main Channel Extension Lockport, IL
- Built in 1907
- Outflow of the Sanitary and Ship Canal
- Limit the diversion of water from the Lake Michigan Watershed into the Des Plaines River.
- Generated 38,017 MWh in 2005 ($1.7 million)

SEPA Sidestream Elevated Pool Aeration

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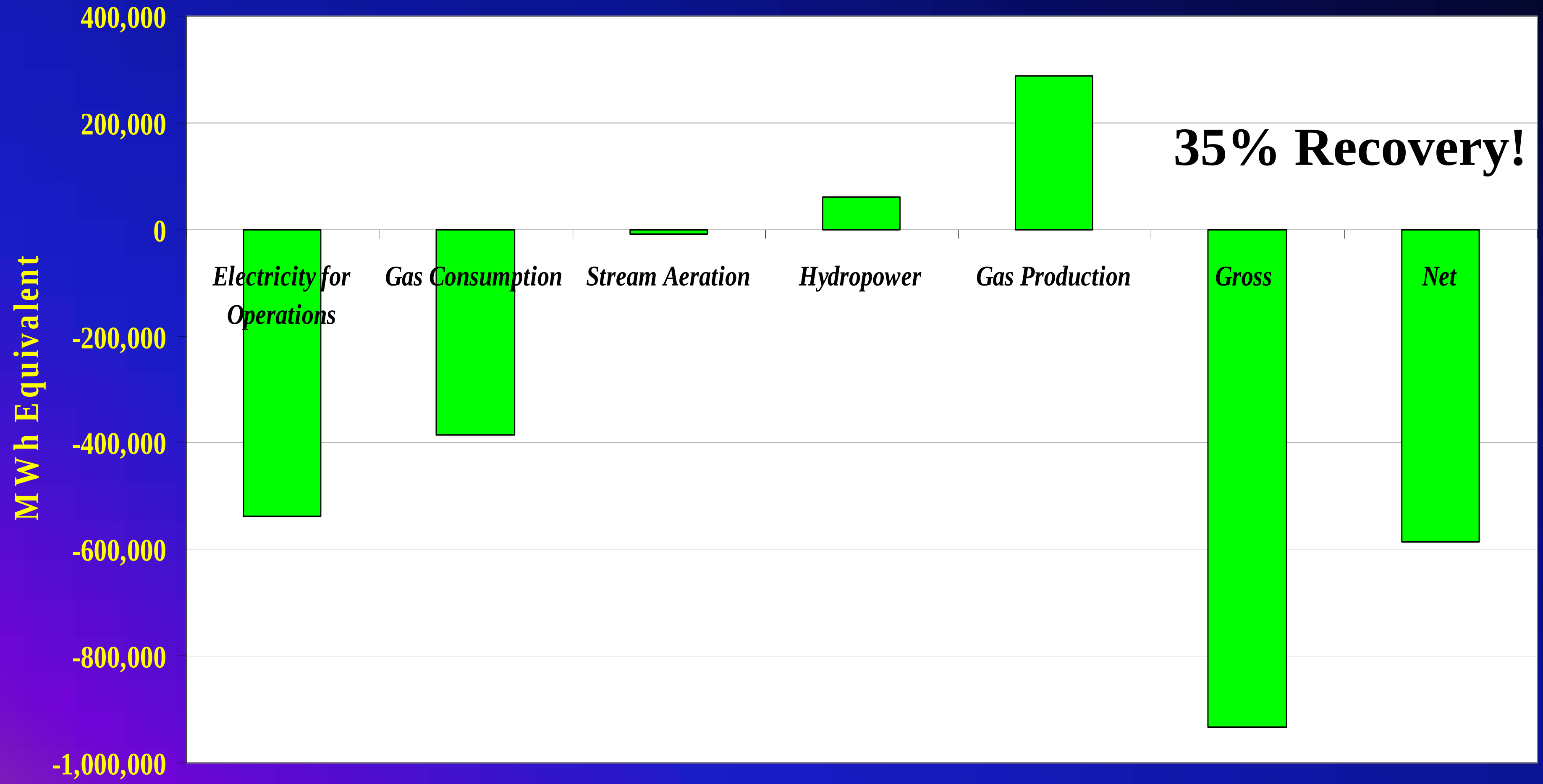
Energy Balance in WRP Operations and Waterway Management - 2005 Actual



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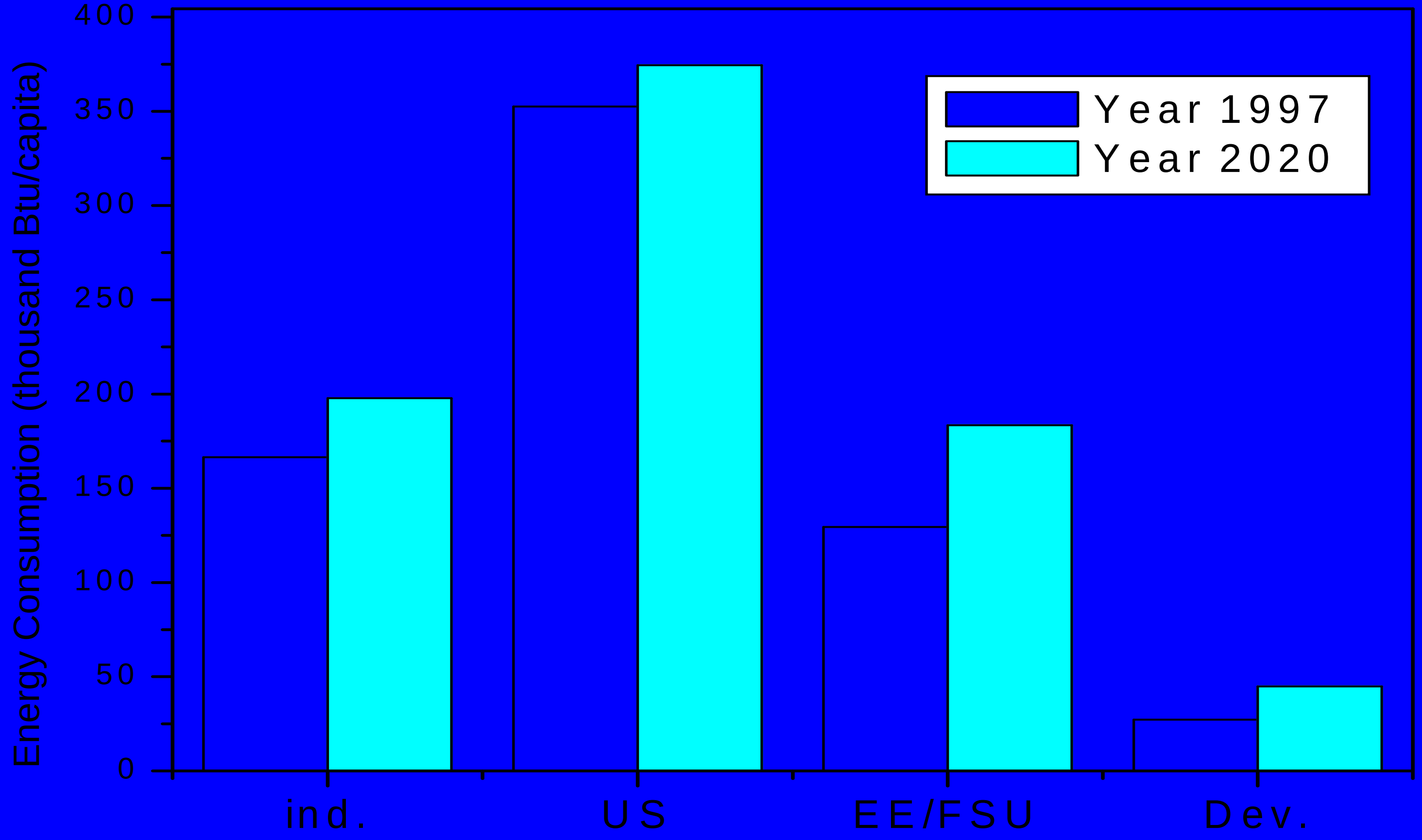
U. S. Policy (2002)

- **Voluntary, Incentive-Based**
- **Slow Growth of Emissions**
- **Strengthen Science, Technology, Institutions**
- **Enhance International Cooperation**
- **Reduce GGI by 18% from 2002 - 2012**
  - ***GGI = GGE/Economic Activity***
  - ***Project 100MMT Annual Reduction by 2012***

World Energy/Capita Consumption by Region



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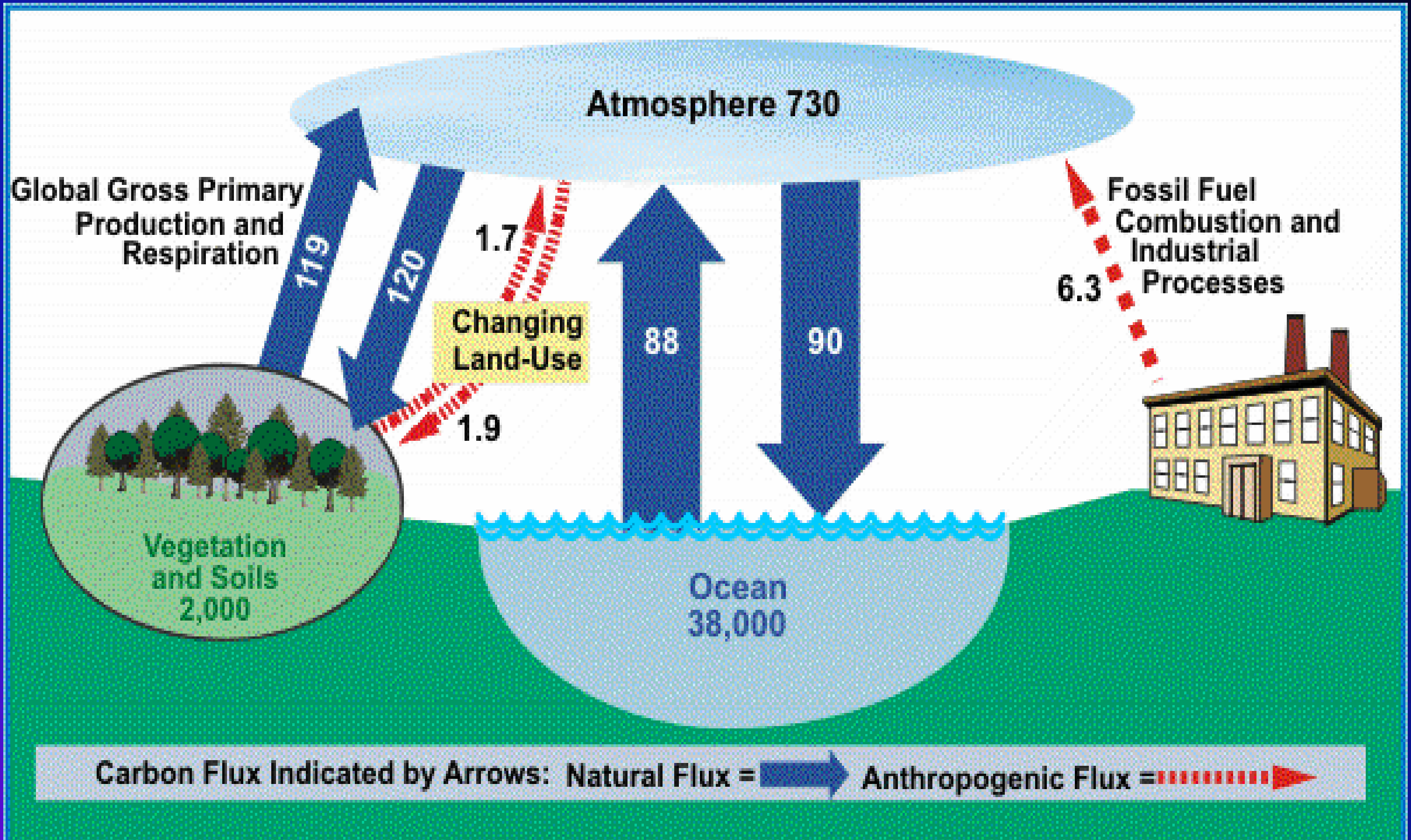

Source: Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (U.K., 2001)

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Greenhouse Gases

- Water Vapor (9 - 26%)
- Carbon Dioxide (CO_2) (36 -70%)
- Methane (CH_4) (4 - 9%) {WRPs #6}
  - *21 times the heat-trapping potential CO_2*
- Ozone (O_3) (3 - 7%)
- Nitrous Oxide (N_2O) {Human Sewage #4}
  - *300 time the heat-trapping potential CO_2*

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Greenhouse Gas Emissions

- **75% Energy Related (Mostly CO_2)**
  - ***50% Stationary Sources (Power Plants)***
  - ***30% Transportation***
- **Industry**
- **US Inventory: million metric tons CO_2 equivalents (MMT CO_2e)**
- **CO_2 concentration in the atmosphere:**
  - ***~8,000 B.C. - Industrial Revolution: 280 ppmv***
  - ***200 years: + 50 ppmv***
  - ***33 years (1973 - 2006): + 50ppmv***

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MWRDGC Global Warming Initiatives

- **Form a Workgroup to Inform Policy**
- **Conduct literature review**
  - ***Greenhouse gas emissions from wastewater treatment***
  - ***Potential corrective action***
- **Verify Fugitive emissions at MWRDGC facility**
  - ***Workplan complete***
  - ***Sampling scheduled for summer ‘08***
- **Pursue corrective action**
- **Determine carbon footprint of operations**

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“Control, Reduction and Utilization of Greenhouse Gases in Wastewater Treatment”

- GHG: Methane (CH_4), Nitrous Oxide (N_2O)
- CH_4 : sixth largest atmospheric contribution
  - *21 times the heat-trapping capacity*
  - *Anaerobic processes: low oxygen pockets, concentration tanks*
- N_2O : fourth largest atmospheric contribution
  - *300 times the heat-trapping capacity*
  - *nitrification, sludge thermal drying*

Kozak, 2007

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“Control, Reduction and Utilization of Greenhouse Gases in Wastewater Treatment” (Con’t)

- Control Methane:
  - *Beneficial use*
  - *Flare*
  - *Remove from centrate*
- Control Nitrous Oxide
  - *Intermittent nitrous oxide, bacteria genera*

Recommend: Measure fugitive emissions

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CH_4 Emissions (IPCC)

$$CH_4 = \left[\sum_{i,j} (EF_j) \right] (TOW - S) - R$$

CH_4 = Total methane emissions from domestic wastewater (kg/year)

i = Income group (rural, urban high income, urban low income)

j = Each treatment/discharge pathway or system, i.e. AEROBIC AND ANAEROBIC TREATMENT

EF_j = Emission factor (kg CH_4/kg BOD)

TOW = Total organics in wastewater in inventory year (kg BOD/ year)

S = Organic component removed as sludge in inventory year
(kg BOD/yr)

R = Amount of CH_4 recovered in inventory year (kg CH_4/yr)

CH_4 Emissions (IPCC) (cont.)

$$EF_j = B_0 \cdot MCF_j$$

B_0	=	**Maximum CH4 producing capacity (kg CH4 /kg BOD)**
	=	**0.6 kg CH_4 /kg BOD (IPCC)**
	=	**0.4 kg CH_4 /kg BOD (NACWA)**
MF_j	=	**Methane correction factor**
	=	**0.1 (Aerobic Treatment of Wastewater)**
	=	**1.0 (Anaerobic Treatment of Sludge)**

DISTRICT EMISSIONS (2000)

CH_4	=	**32.37×10^6 kg CH_4 (IPCC)**
	=	**679.7×10^6 CO_2 equivalents (IPCC)**
CH_4	=	**12.35×10^6 kg CH_4 (NACWA)**
	=	**259.4×10^6 CO_2 equivalents (NACWA)**

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N_2O Emissions (IPCC)

$$N_2O_{Plants} = P \cdot T_{Plant} \cdot F_{IND-COM} \cdot EF_{Plant}$$

N_2O_{Plants}	=	Total N_2O emissions from plants, kg N_2O/year
P	=	Population, persons
T_{Plant}	=	Degree of use of wastewater treatment plants per capita, unitless
$F_{IND-COM}$	=	Fraction of industrial and commercial co-discharged protein, unitless
EF_{Plant}	=	Emission factor, kg N_2O/person/year

$$N_2O_{Effluent} = N_{Effluent} \cdot EF_{Effluent} \cdot 44/28$$

$N_2O_{Effluent}$	=	Total N_2O emissions from effluents, kg N_2O/yr
$N_{Effluent}$	=	Nitrogen in the effluent discharged to aquatic environments, kg N/yr
$EF_{Efflu-ent}$	=	Emission factor, kg N_2O-N/kg N
44/28	=	Conversion of kg N_2O-N to kg N_2O

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N_2O Emissions (IPCC)

$F_{IND\text{-}COM}$	=	1.25 (IPCC)
	=	1.0 (NACWA)

DISTRICT EMISSIONS (2000)

N_2O = 49,353 kg N_2O (IPCC)
= 14.81×10^6 CO_2 equivalents (IPCC)

N_2O = 45,120 kg N_2O(NACWA)
= 13.54×10^6 CO_2 equivalents (NACWA)

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Measurement of Fugitive CH_4, N_2O

- Commence July 28, 2008
- Collaboration with UIC, Dept of Earth and Environmental Science
- Verify IPCC/ NACWA estimates
- Sample unit process operations
- Sample fence-line during atmospheric inversion (speculative)
- Phase I

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Carbon Footprint by Source (*2005*)

Source	*Tons CO_2*
Electricity	520,419
Gas (Purchase)	9,276
Biogas Generated	33,180
Fugitive Methane	747,670 (IPCC)/ 285,340 (NACWA)
Nitrous Oxide	16,280 (IPCC)/ 14,894 (NACWA)
Carbon Conversion (biogenic)	118,867*
Hydropower	25,490
Biogas Utilization	26,957
Net	1,274,378 (IPCC)/ 810,662 (NACWA)

CAWS Water Use by Energy Sector – 2005 Actual

CAWS WW Flow (MG)	Treatment (MWh Eq)	Energy Sector	Water Use (MG)	Energy Produced MWh
406,047	567,924	Fisk Gen Plant	81,100	1,602,180
		Crawford Gen	183,700	3,201,844
		Citgo	1,933	
		Premcor	66	
		Total	***266,799***	***4,804,024***
		Hydropower	518,950	38,017

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Reasons for Optimism

- Tian, Granato, Cox, Pietz, Carlson, Abedin (2008) "Carbon Sequestration of Biosolids: Extrapolating from Fulton County Case Study to Evaluate its Potential for the United States and Worldwide"
- 1974 – 2004: 1 million tons applied
- Amorphous Fe, Al stabilize C
- Increase soil microorganisms that utilize CO2
- Additional 80,000 tons C sequestered
- "missing C sink?" ~ 2.1 %

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Reasons for Optimism

Direct Electricity for Hydrogen Generation from Wastewater and other Waste Biomass Using Microbial Fuel Cell Technologies, Professor Bruce Logan, Penn State University

Solar-powered Hydrogen Production via Water Splitting with Simultaneous Water Treatment, Professor Michael Hoffmann, Cal Tech

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