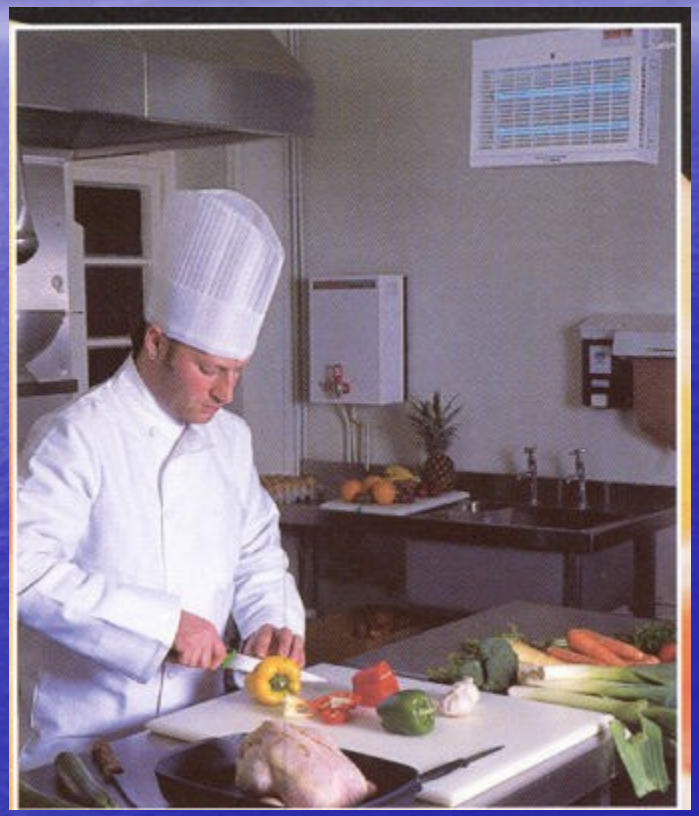
Material Sustainability

The Loudon County Summit
November 14, 2008

David A. Vaccari, Ph.D., P.E., CPEE
Department of Civil, Environmental and Ocean Engineering
dvaccari@stevens.edu
http://personal.stevens.edu/~dvaccari/

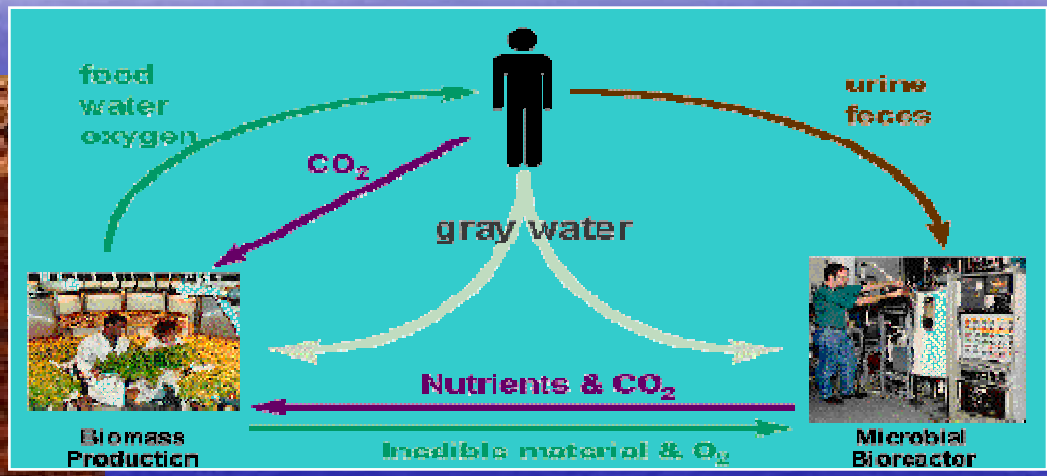
STEVENS Institute of Technology

Food Preparation at Home



STEVENS
Institute of Technology

Cooking in Space – Advanced Life Support

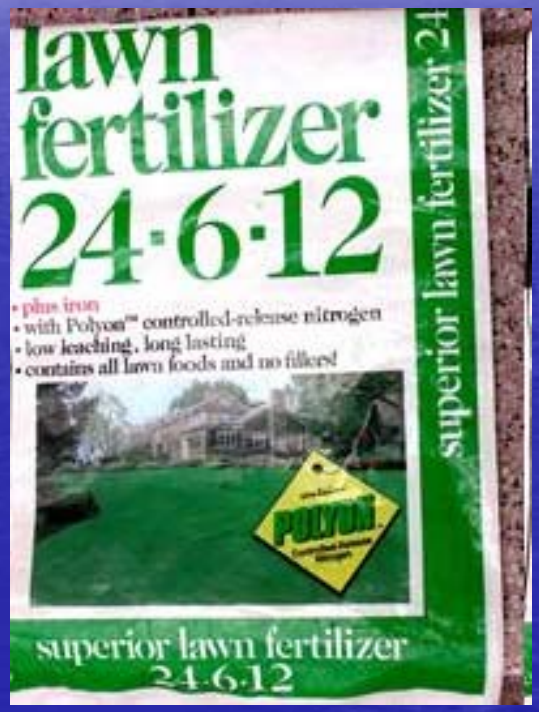


STEVENS Institute of Technology

Biosphere I

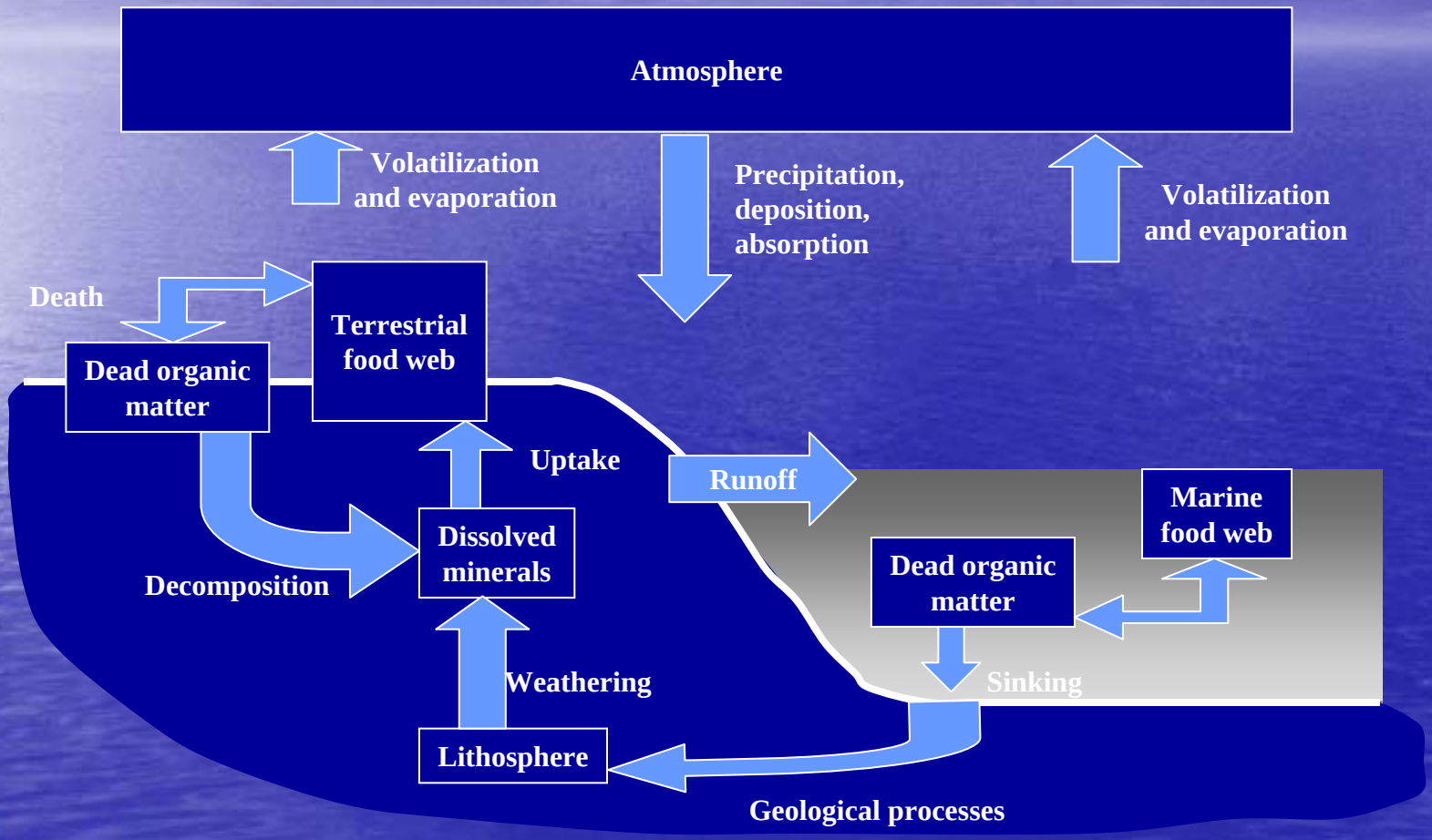
What do plants need to grow?

- Sunlight
- Soil/substrate
- CO_2 and H_2O
- Macronutrients: N, P, K
  S, Ca, Mg
- Micronutrients: Fe, Cl, Mg



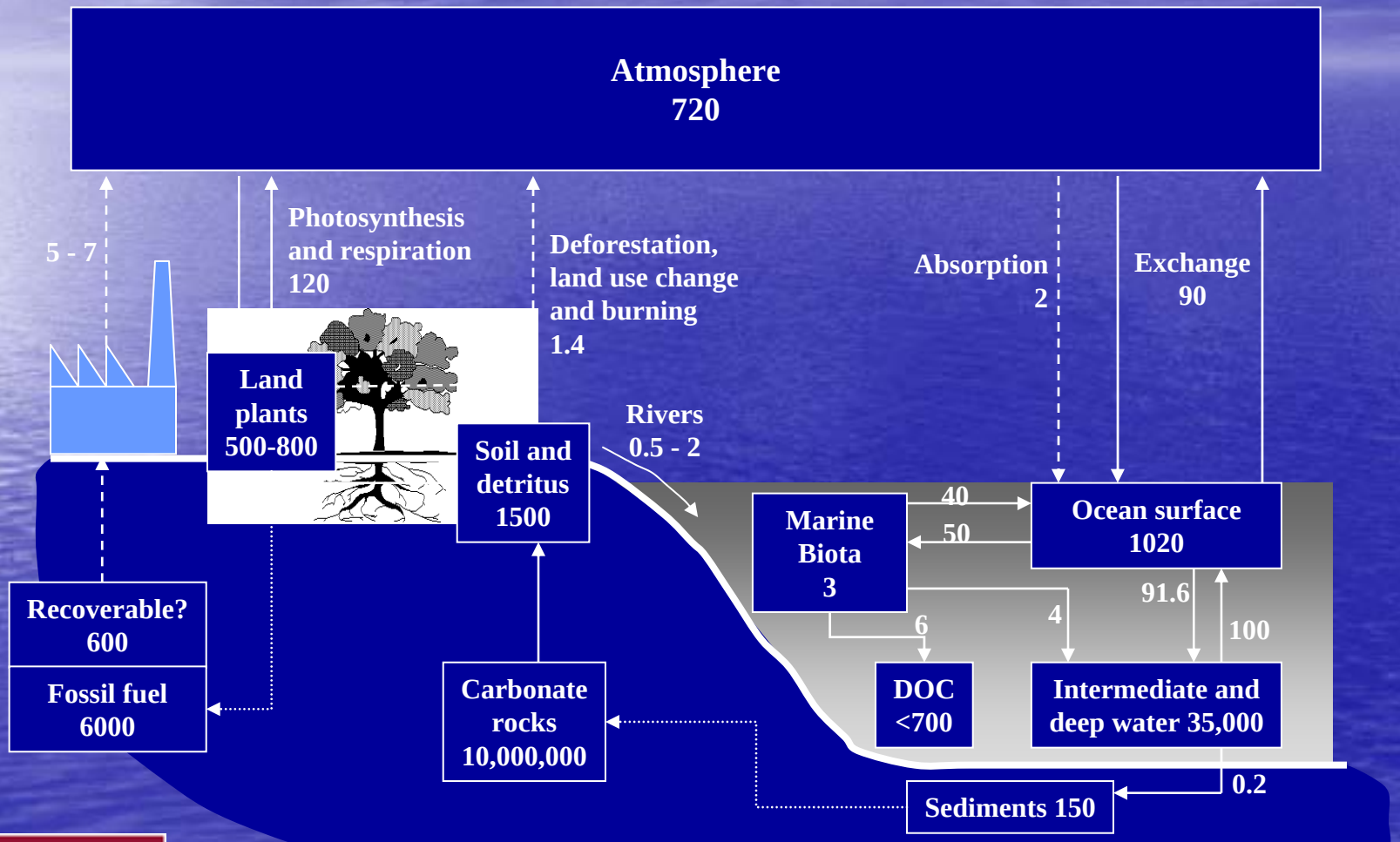
STEVENS Institute of Technology

Biogeochemical cycles



STEVENS Institute of Technology

The global carbon cycle (Tg or Tg/yr)



STEVENS Institute of Technology

Residence times

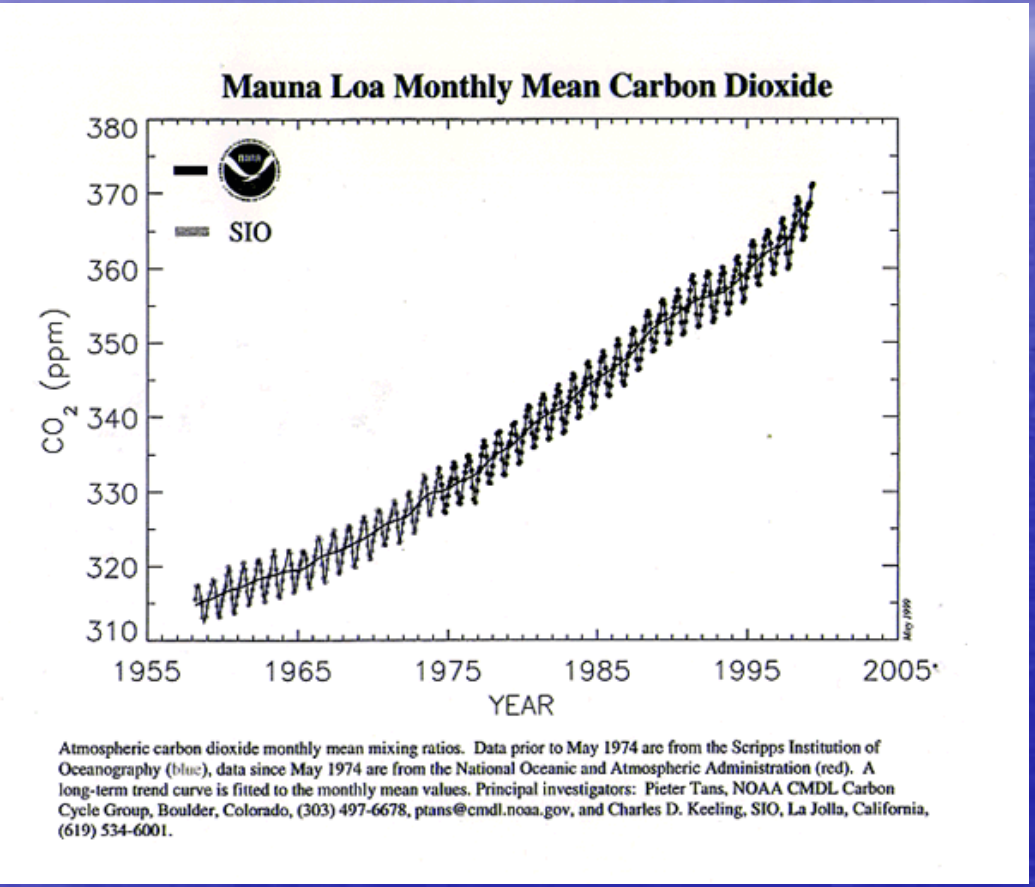
$$\frac{720}{120+90} = \frac{720}{210\ \ per\ \ yr} = 3.4\ years$$

$$\frac{3 to 5\ per\ year}{720} \cong 0.55\%\ per\ year$$

$$Actual: \frac{1.5\ ppmv/yr}{380\ ppmv} \cdot 100\% = 0.4\%/yr$$

STEVENS Institute of Technology

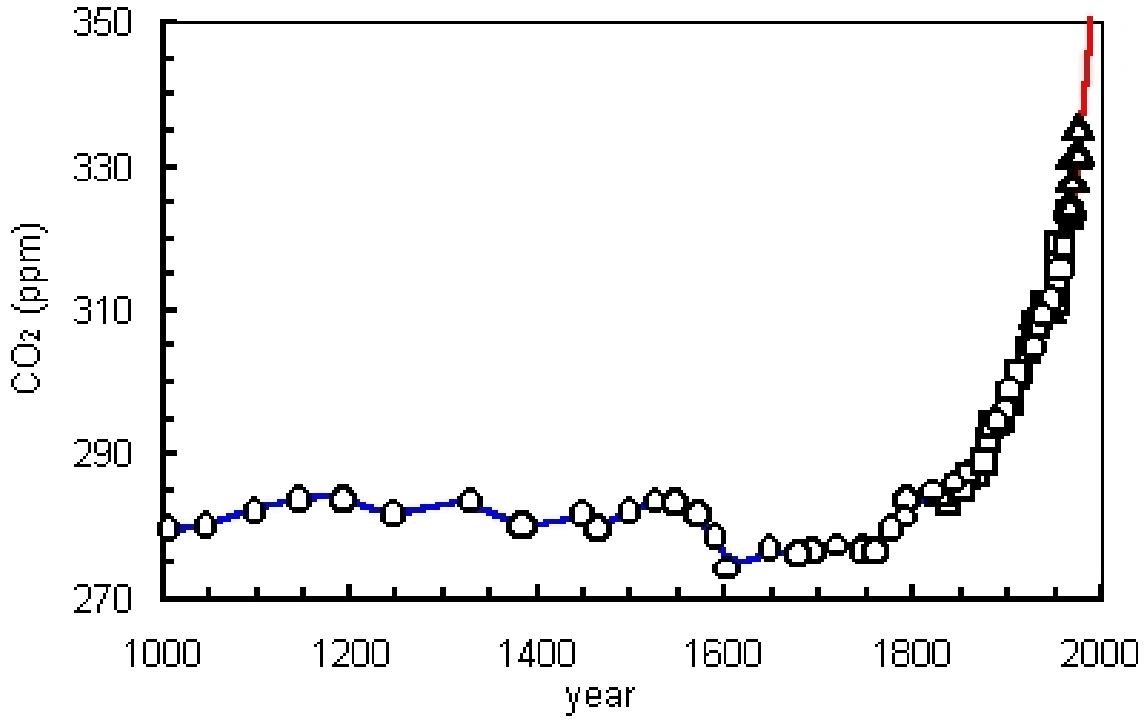
The fertilizer in the air



Atmospheric carbon dioxide monthly mean mixing ratios. Data prior to May 1974 are from the Scripps Institution of Oceanography (blue), data since May 1974 are from the National Oceanic and Atmospheric Administration (red). A long-term trend curve is fitted to the monthly mean values. Principal investigators: Pieter Tans, NOAA CMDL Carbon Cycle Group, Boulder, Colorado, (303) 497-6678, ptans@cmdl.noaa.gov, and Charles D. Keeling, SIO, La Jolla, California, (619) 534-6001.

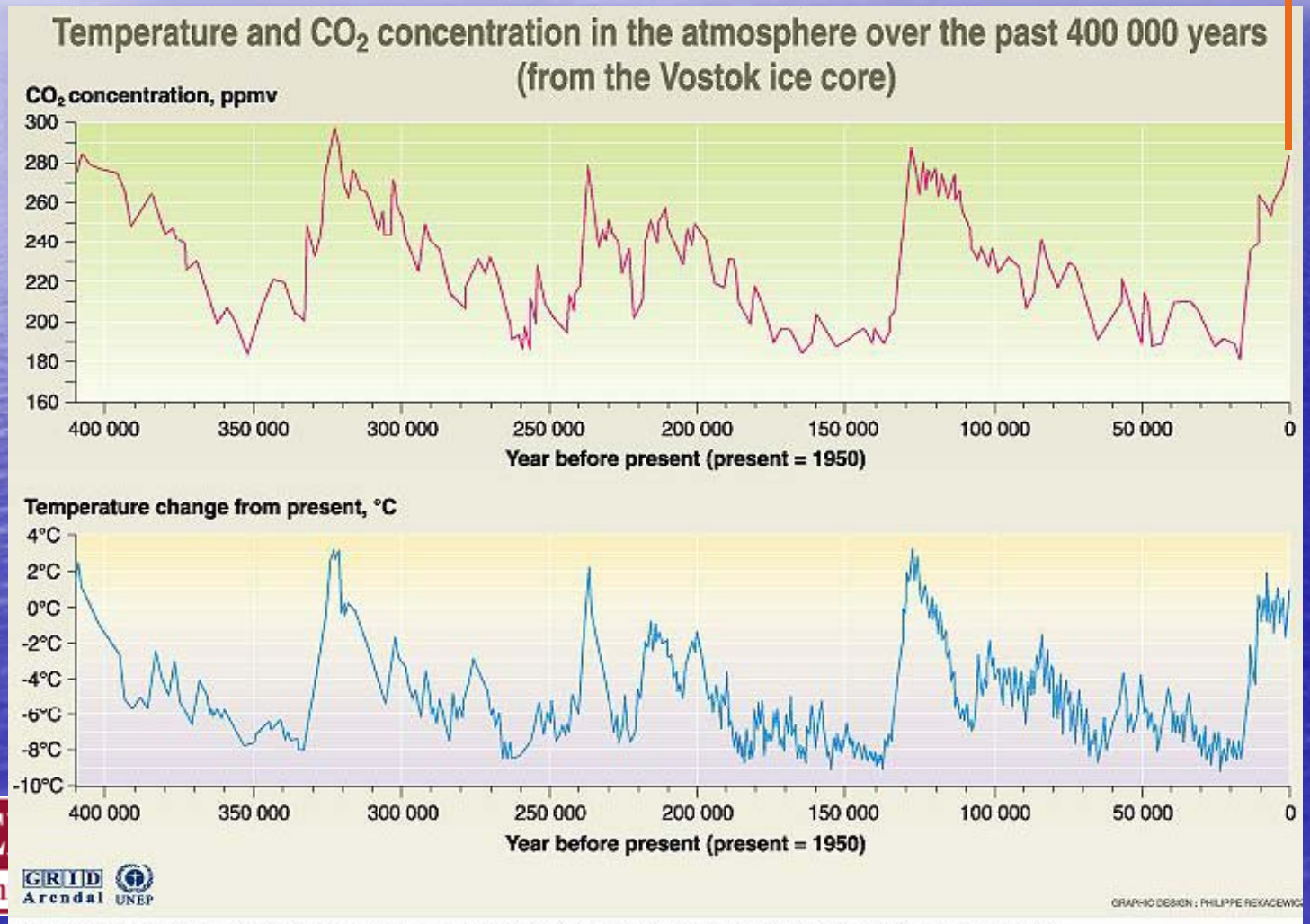
STEVENS Institute of Technology

Longer term view



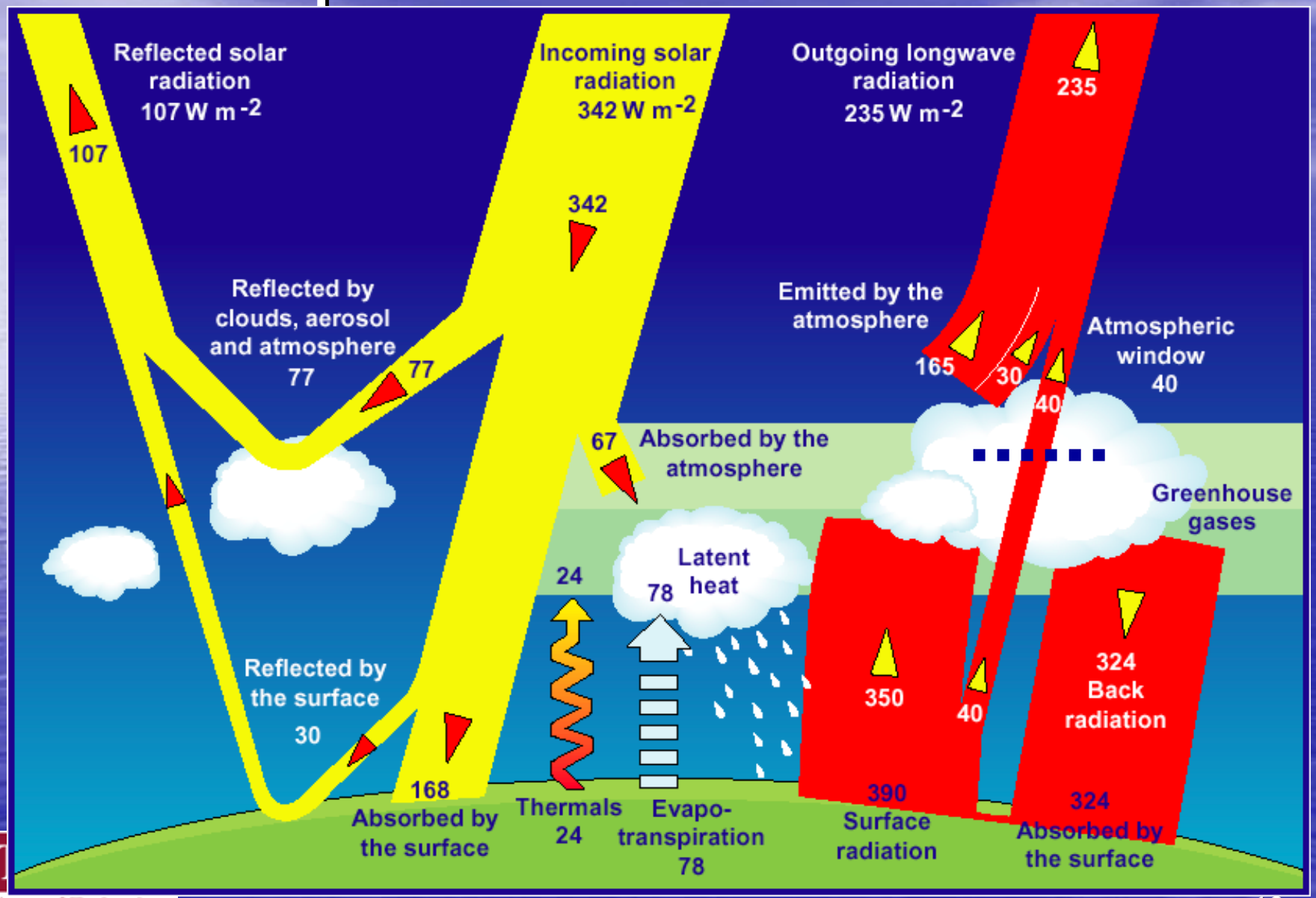
STEVENS Institute of Technology

Even longer



STEVE Institute of Tech

Atmospheric radiation balance



Institute of Technology

A naive energy balance:

- Current heat trapping is 2.64 W/m^2
- If all this went into heating the atmosphere and the top 100 meters of the ocean:

  ΔT = 0.26°C/year

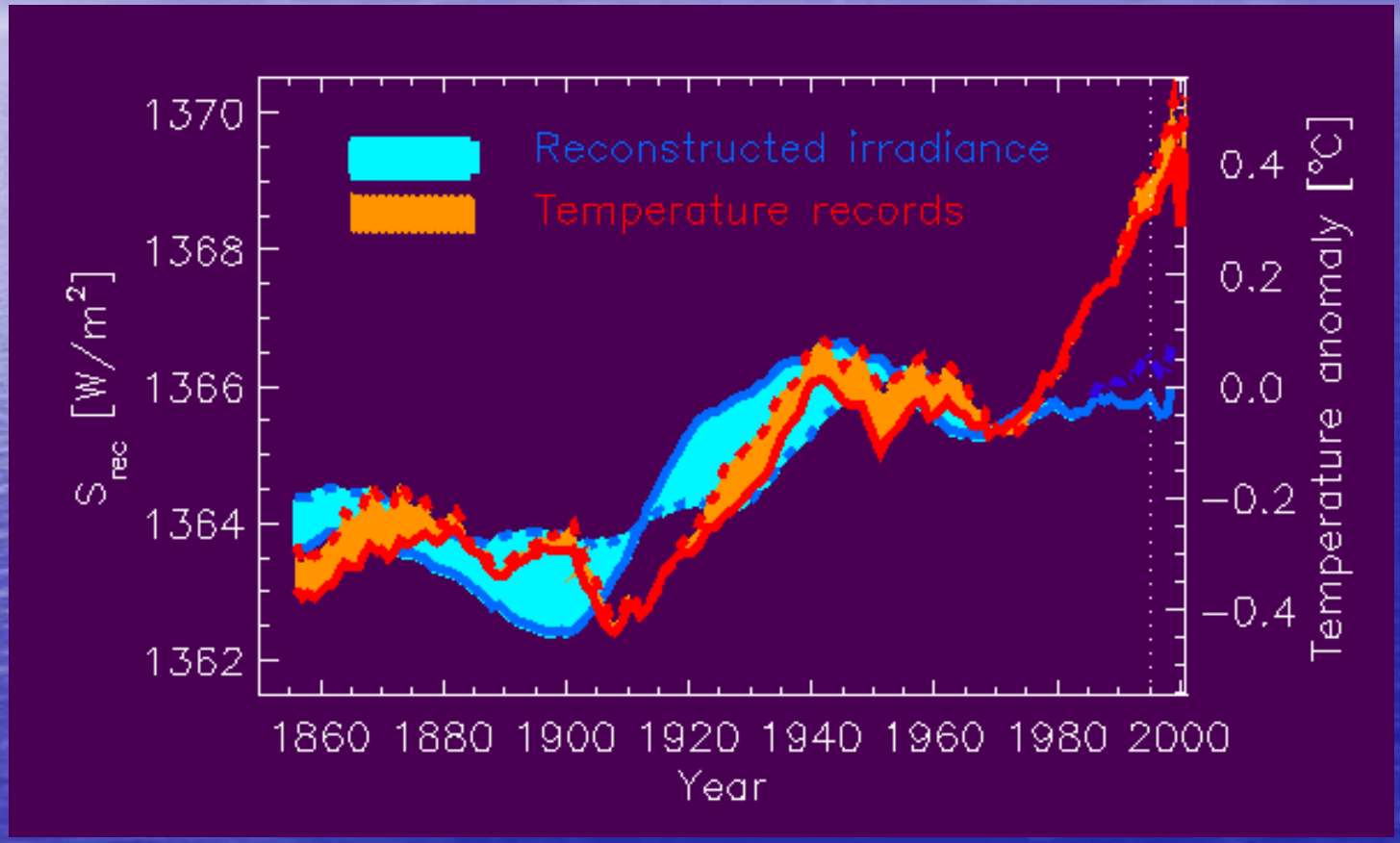
- Heat trapping from CO2 doubling will be 4.35 W/m^2
- Resulting atmospheric heating would be:

  ΔT = 0.42°C/year

- Increase in the last century has been about 0.007°C/year
- This is 37 times less than 0.26°C/yr
- WHERE DOES THE REST OF THE HEAT GO?

STEVENS Institute of Technology

Solar radiance does not explain the observed temperature anomaly



STEVENS Institute of Technology

Reserve lifetime

Fossil Fuels 600 → Combustion 5

$$\frac{600\,Tg}{6\,Tg/yr} = 100\,yr$$

Elemental reserves

- Iron 300 yrs
- Aluminium 280 yrs
- Titanium 100+ yrs
- Copper 40 yrs
- Zinc 35 yrs
- Nickel 130 yrs
- Cobalt 333 yrs
- Chromium 625 yrs

http://www.aviationindustrygroup.com/downloads/ae06rnuttall-1373-1409.pdf

Elemental reserves considered low

- **Tantalum** (cutting tools, optical coating, hi-temp)
- **Mercury** (thermometers, dental, lighting)
- **Cadmium** (reactors, batteries, solder, pigments)
- **Thallium** (glasses, infra-red devices)
- **Gold** (jewelry, circuits, reflectors)
- **Silver** (jewelry, reflectors, photographic)
- **Bismuth** (fuses, pigments)
- **Indium** (bearings, electronics)

STEVENS Institute of Technology

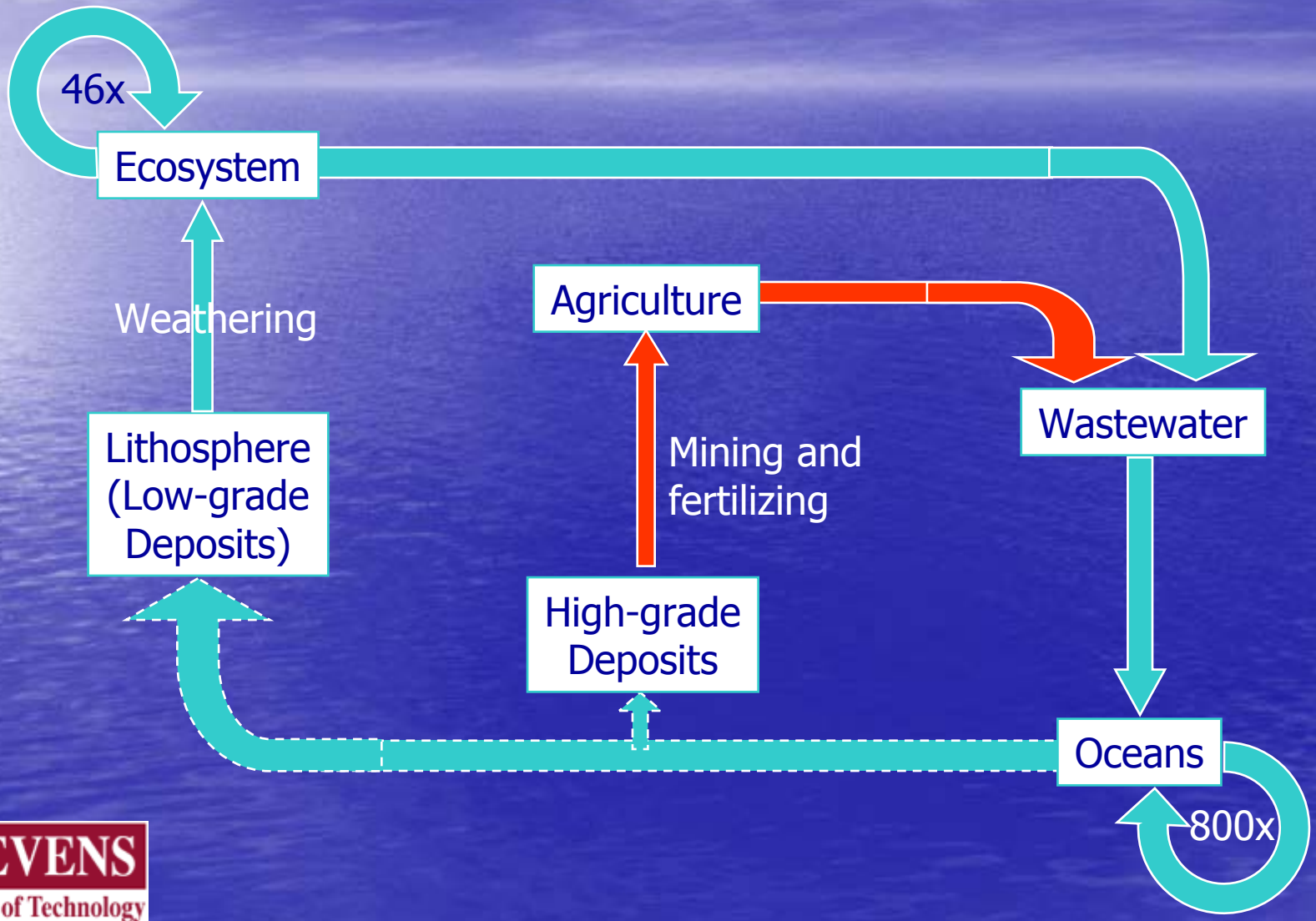
What about phosphorus?

Where do we get our phosphorus from?

How long will it last?

STEVENS Institute of Technology

Phosphorus Cycle



STEVENS Institute of Technology

"Bone Valley" Florida

STEVENS Institute of Technology

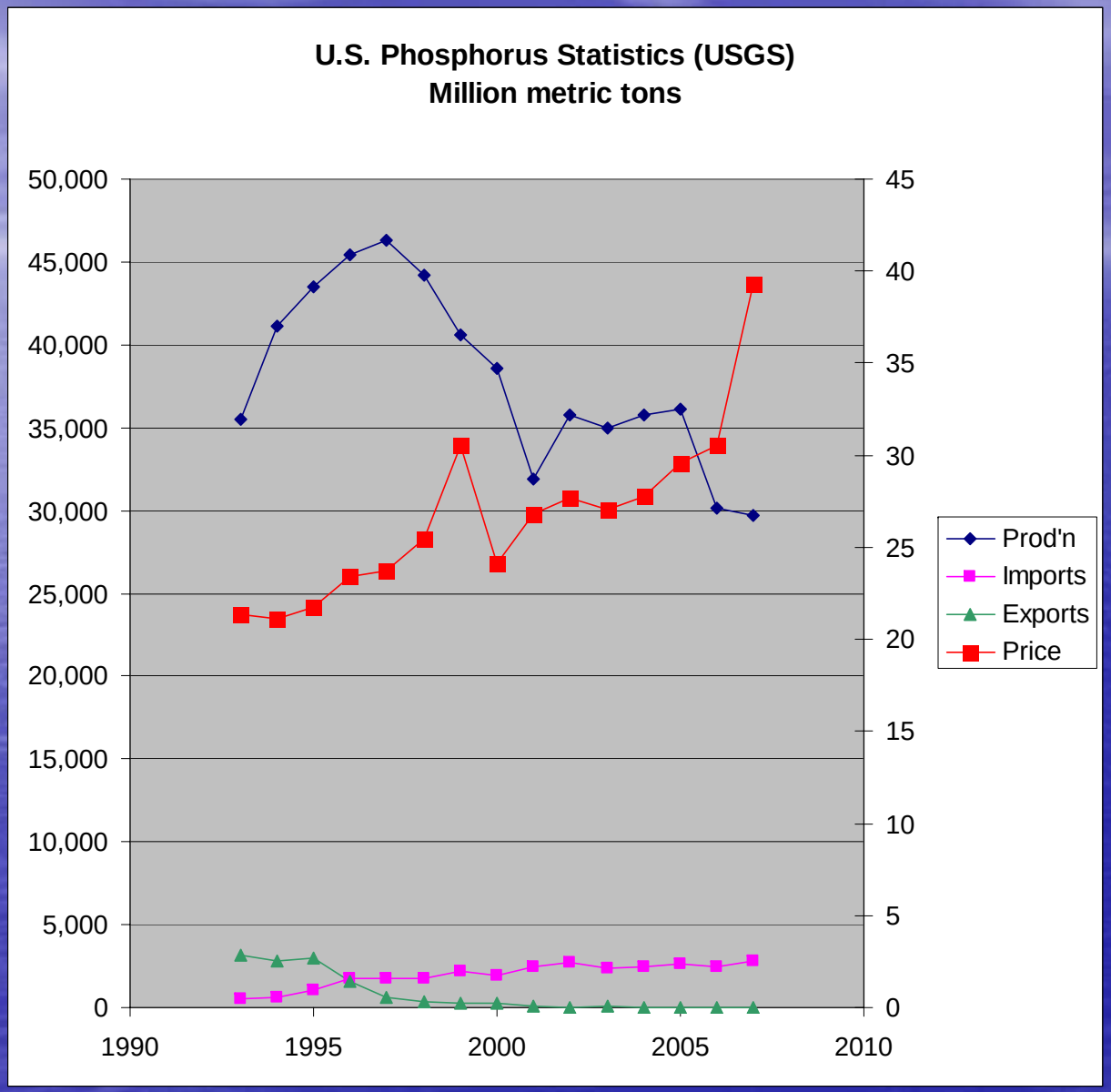
How much phosphorus is left?

TABLE 1. World phosphate rock production, reserves, and reserve base.

Country	Average production, 1997-2001, thousand tons	Reserves[1], million tons	Reserve life[2], years	Reserve base, million tons	Reserve base life[2], years
United States	44,851	1,102	25	4,408	98
Brazil	4,875	364	75	408	84
China	24,134	1,102	46	11,020	457
Israel	4,487	198	44	882	196
Jordan	6,350	992	156	1,873	295
Morocco/ Western Sahara	25,346	6,281	248	23,142	913
Russia	11,020	220	20	1,102	100
Senegal	1,860	55	30	176	95
South Africa	3,152	1,653	524	2,755	874
Syria	1,955	110	56	882	451
Togo	1,917	33	17	66	34
Tunisia	8,697	110	13	661	76
Other countries	12,364	1,322	110	4,408	357
Total (rounded)	**151,000**	**13,224**	**88**	**51,794**	**343**

[1]Reserve and reserve base cost less than $36/ton and $90/ton, respectively. Cost includes capital, operating taxes, royalties (if applicable), miscellaneous costs, and a 15 percent rate of return on investment, FOB mine (1992 costs).
[2]Life based on 1997-2001 five-year average mine production.
Source: U.S. Geological Survey.

STEVENS Institute of Technology



STEVENS Institute of Technology

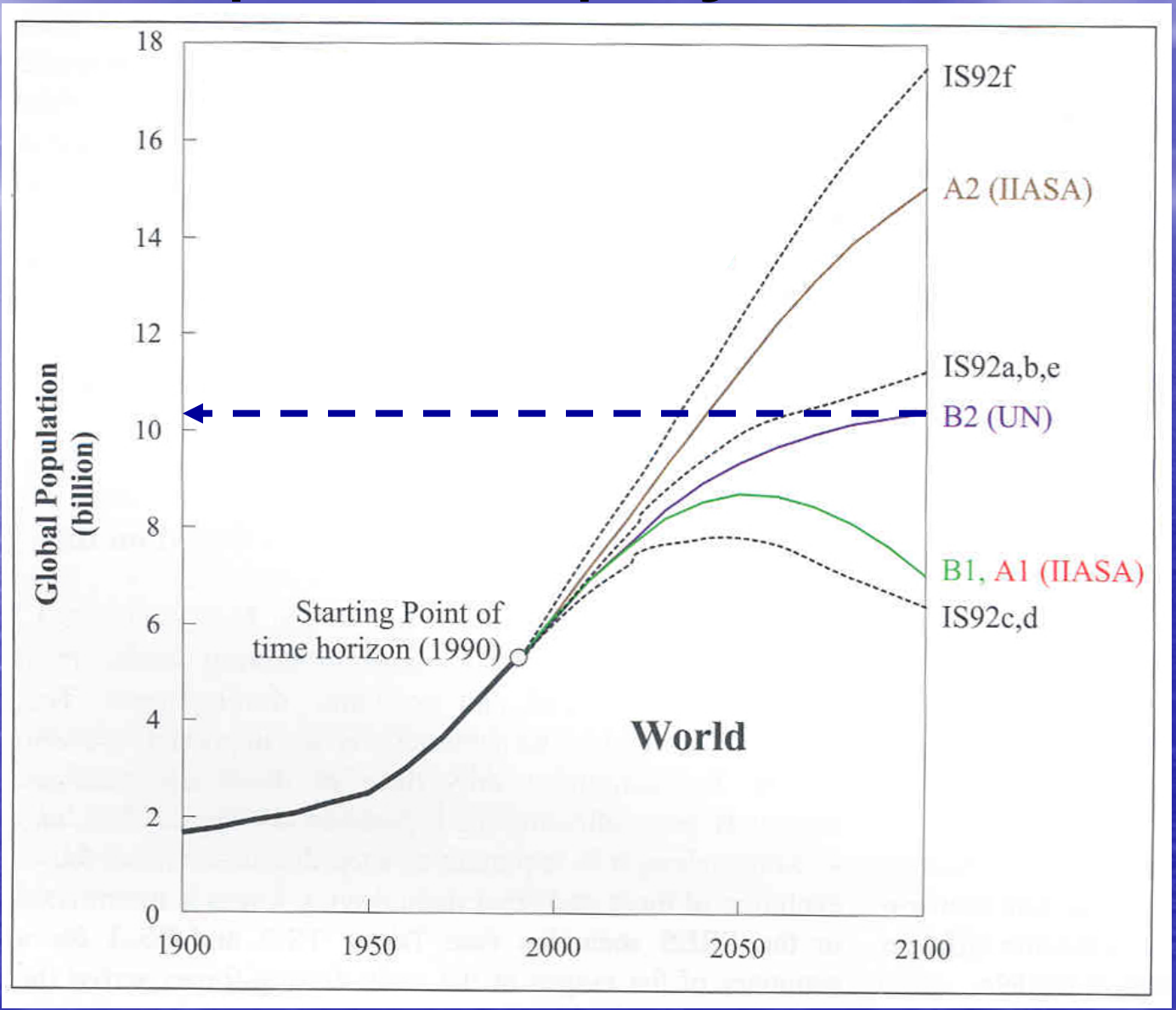
The Earth's Carrying Capacity

Based on world grain production of
2 billion tons per year:

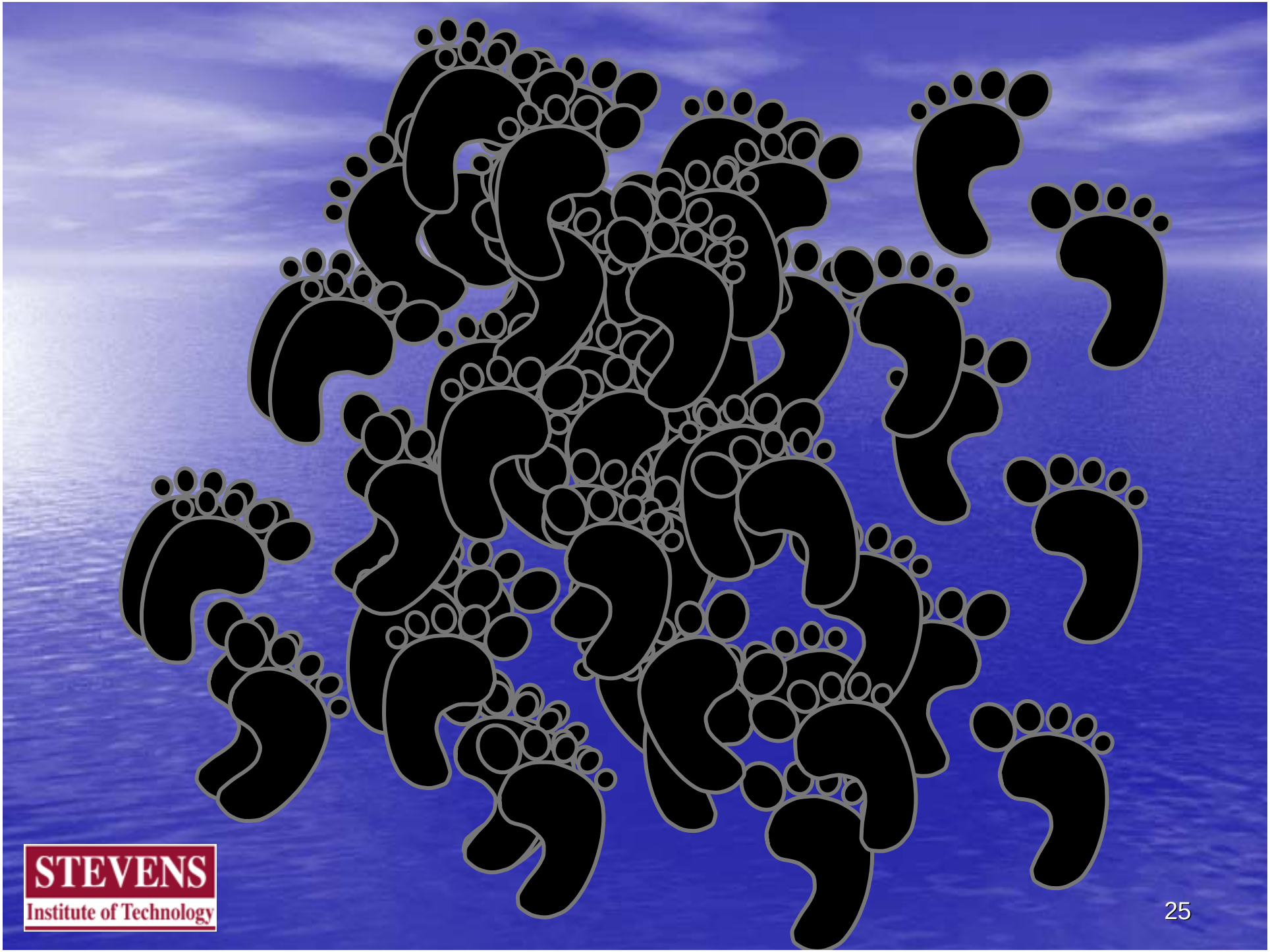
- "Indian" diet . . . . . 10 billion people
- "Mediterranean" diet . . 5 billion people
- "American" diet . . . . . 2.5 billion people

STEVENS Institute of Technology

Population projections

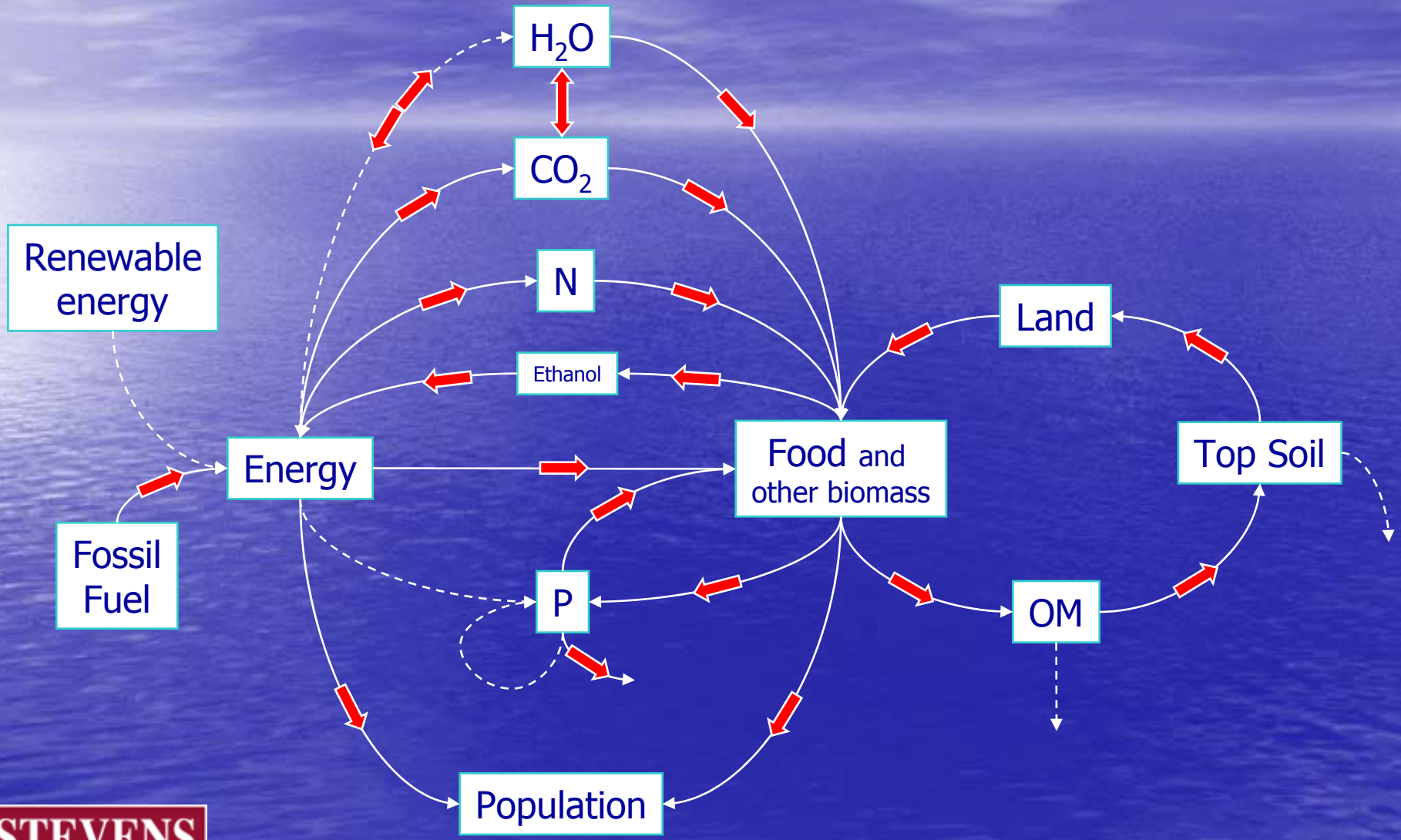


STEVENS Institute of Technology



STEVENS
Institute of Technology

Connections



STEVENS Institute of Technology

What can save us?

- New resource discoveries
  - Unexplored regions?
- New technologies
  - Beneficiation
  - Recovery
- Switch to alternatives
  - There is no alternative for phosphorus in agriculture
- Conservation
  - Increase efficiency of fertilization
  - Prevent erosion/runoff
- Recycling
  - Recover sludge, manure, other biomass
  - Collect urine and other wastes

STEVENS Institute of Technology

What can we do?

Everything!

Especially: Think long-term

What is the most important thing you can do?

Educate yourself

STEVENS Institute of Technology