

Is the future really in algae?

OMEGA for the future of biofuels

OMEGA for the future

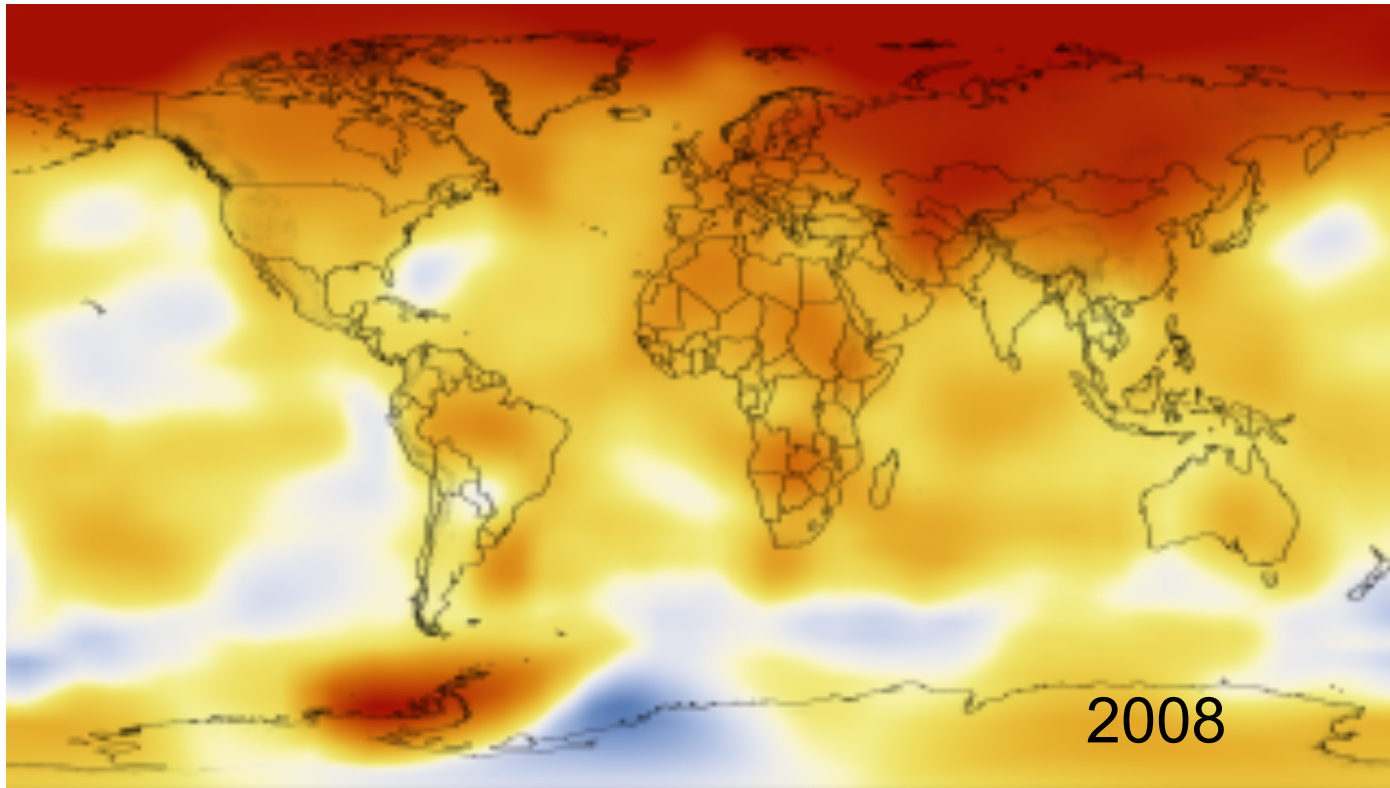
OMEGA

Jonathan Trent, Ph.D.

NASA Ames Research Center
Jonathan.d.trent@nasa.gov

MB Marine Sanctuary

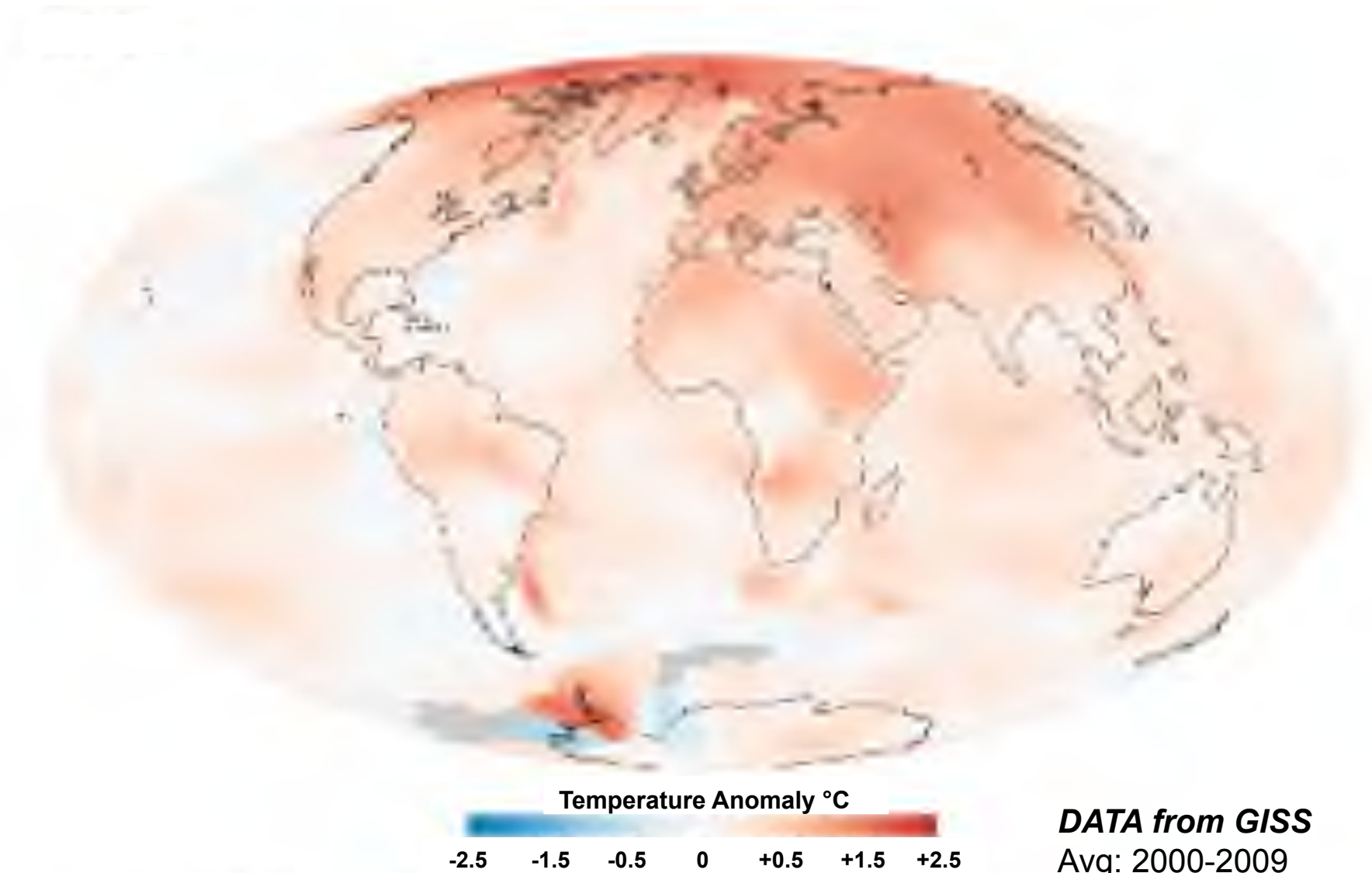
10 April 2010



Temperature Anomaly °C

Data from NASA/Goddard Space Flight Center
James Hansen, Goddard Institute of Space Studies
Robert B. Schmunk, Scientific Visualization Studio

The warmest decade on record...

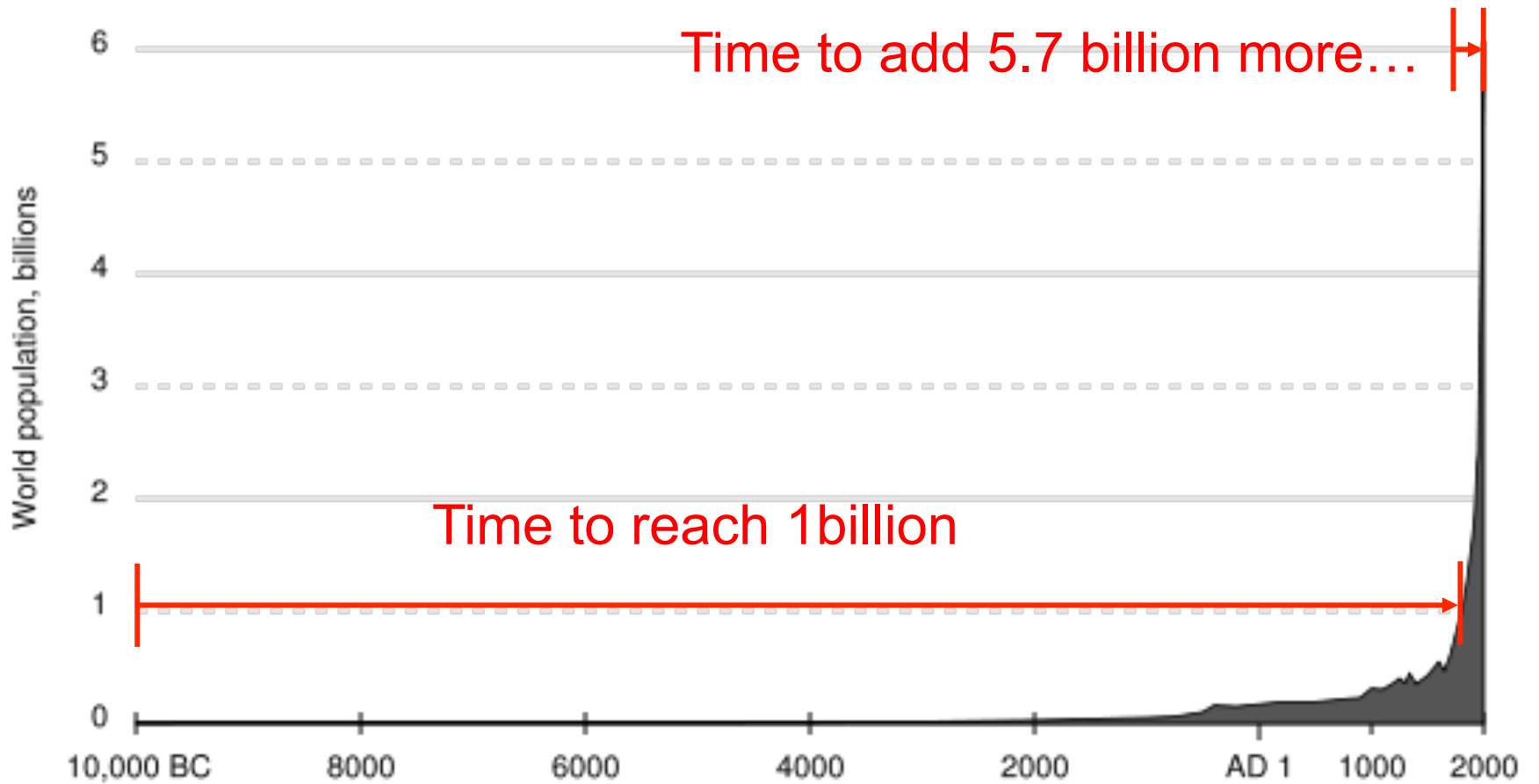


DATA from GISS

Avg: 2000-2009

1951-1980

Limits to growth?

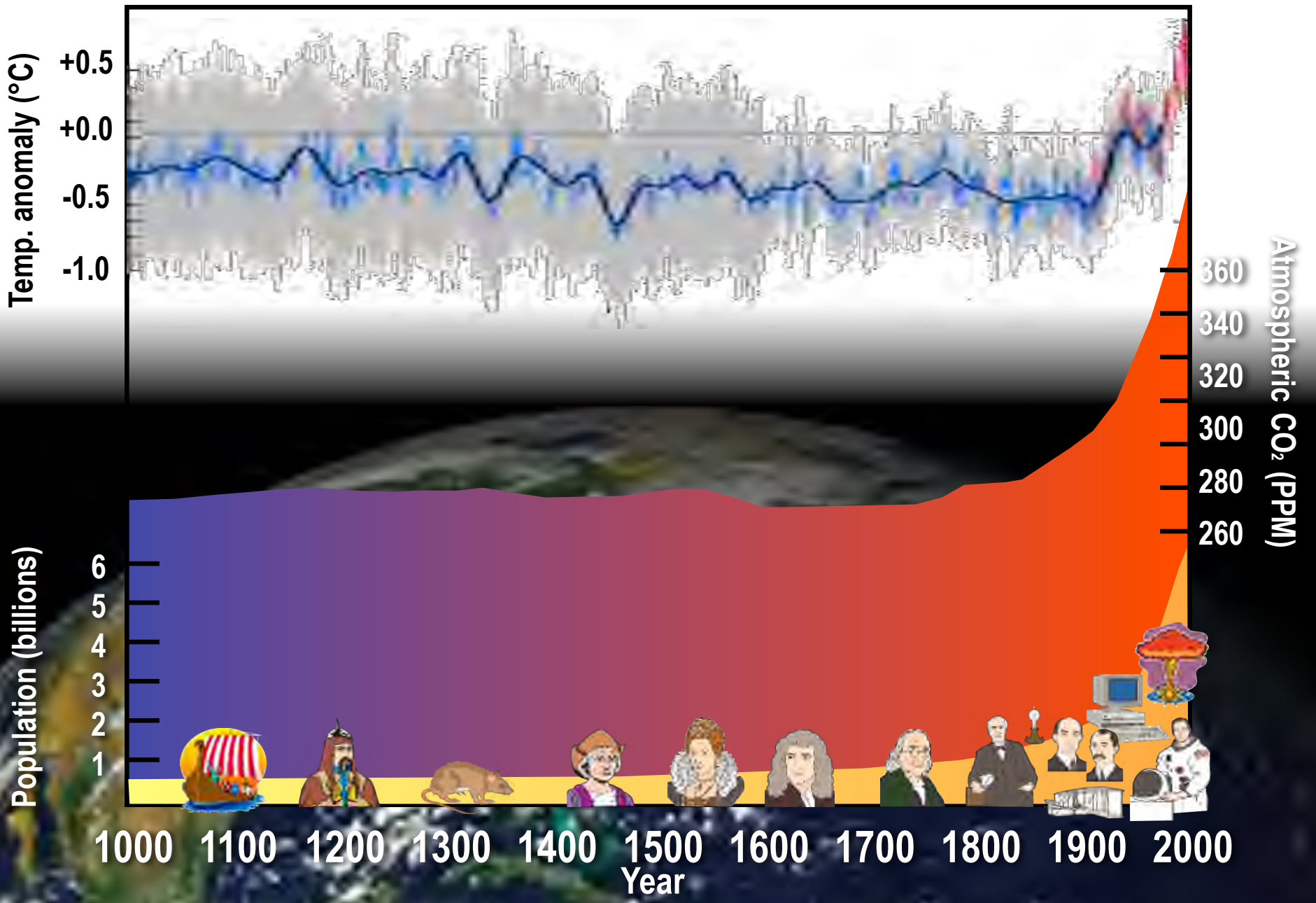




1000 A.D.

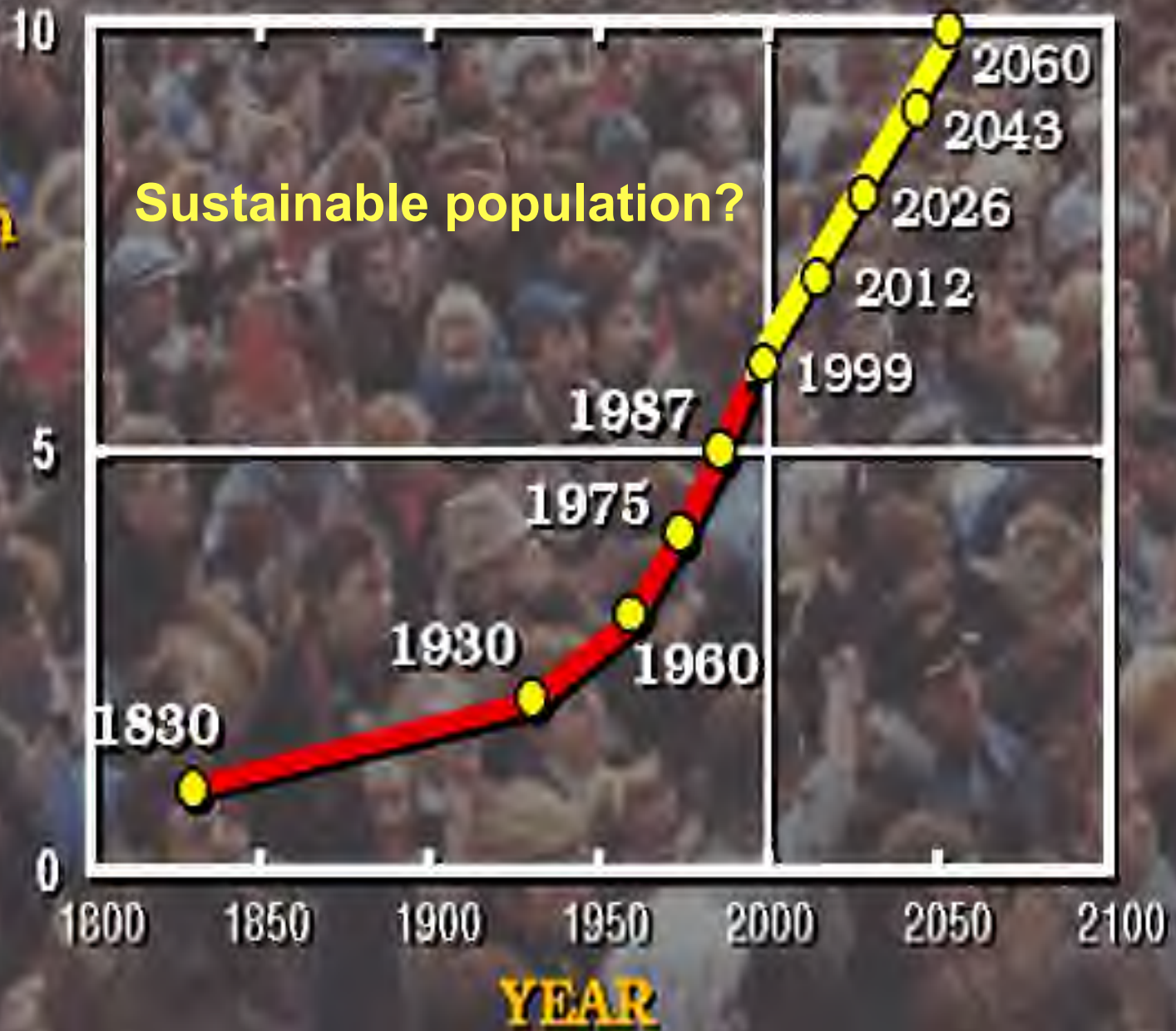
Viking Conquests

Population Connection



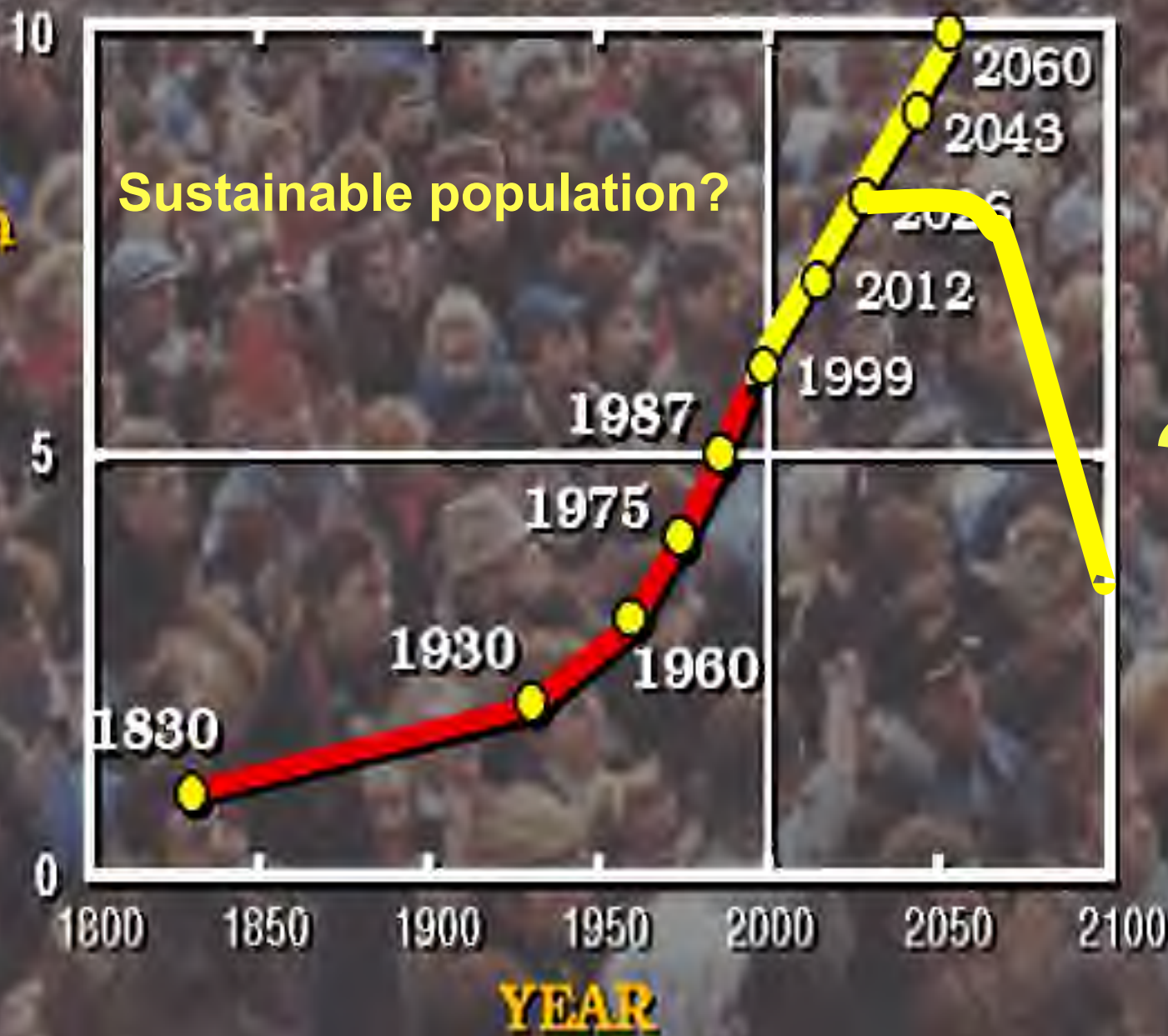
What is the meaning of sustainable?

**World
Population
(Billions)**

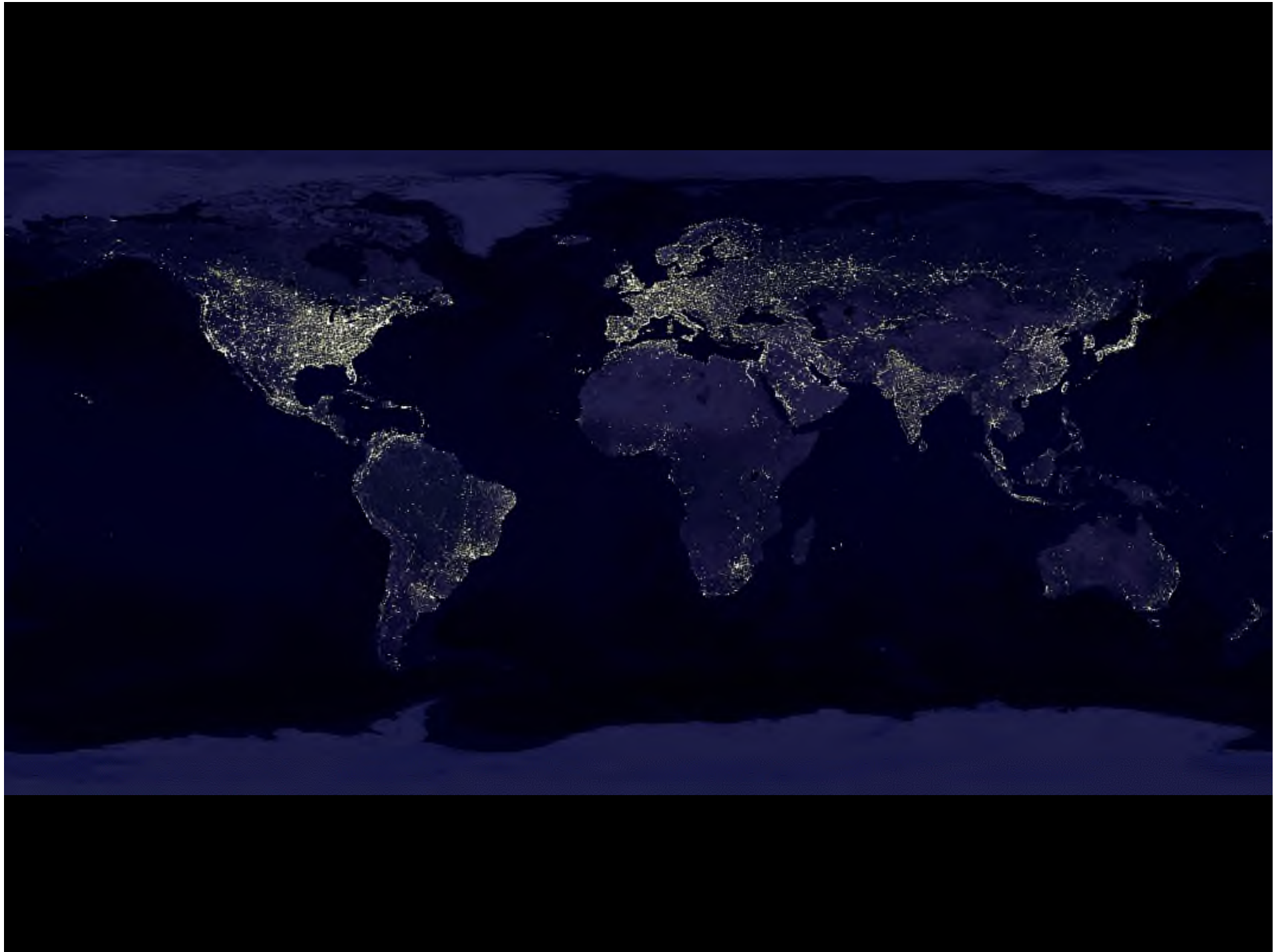


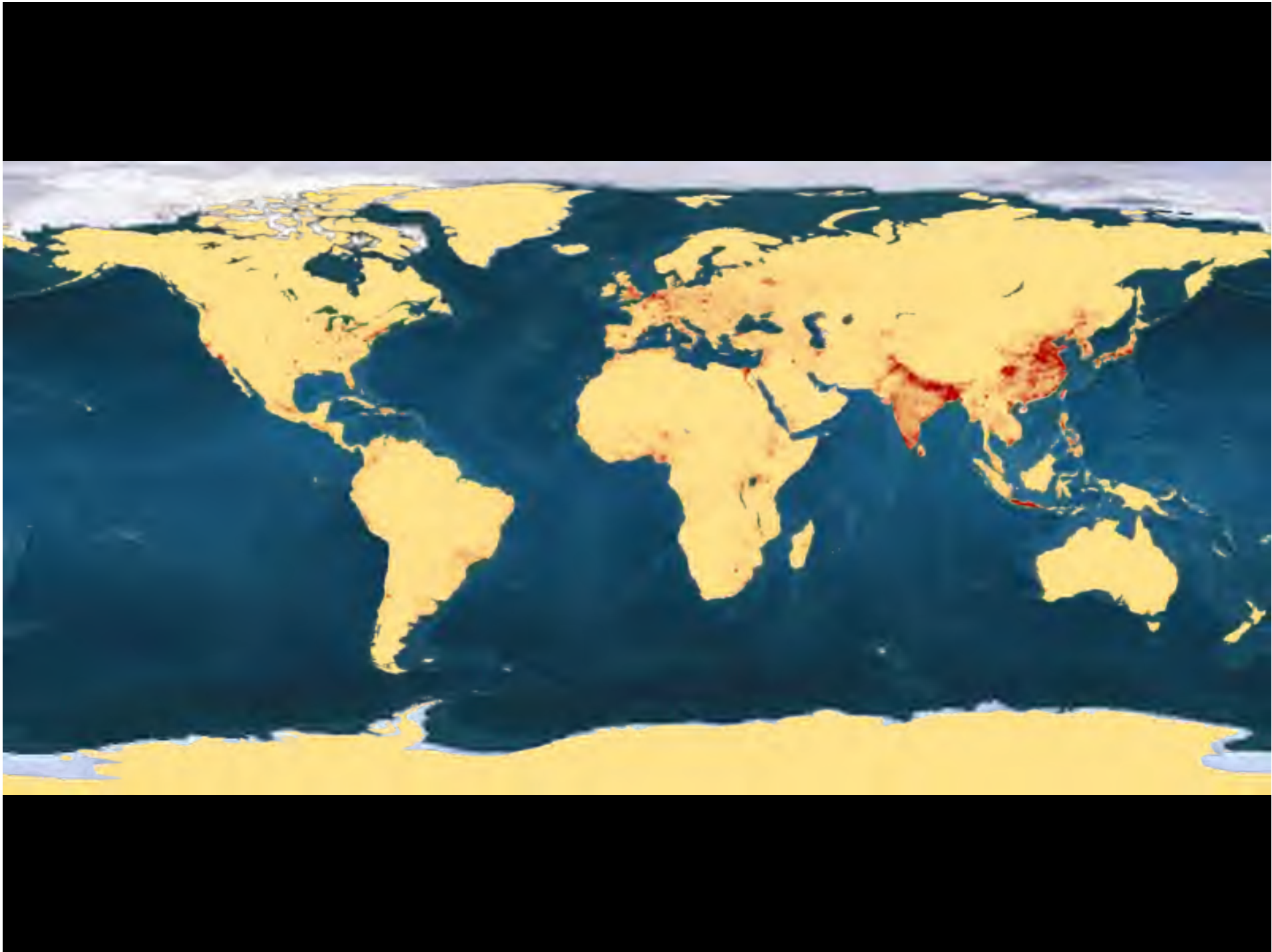
World Population (Billions)

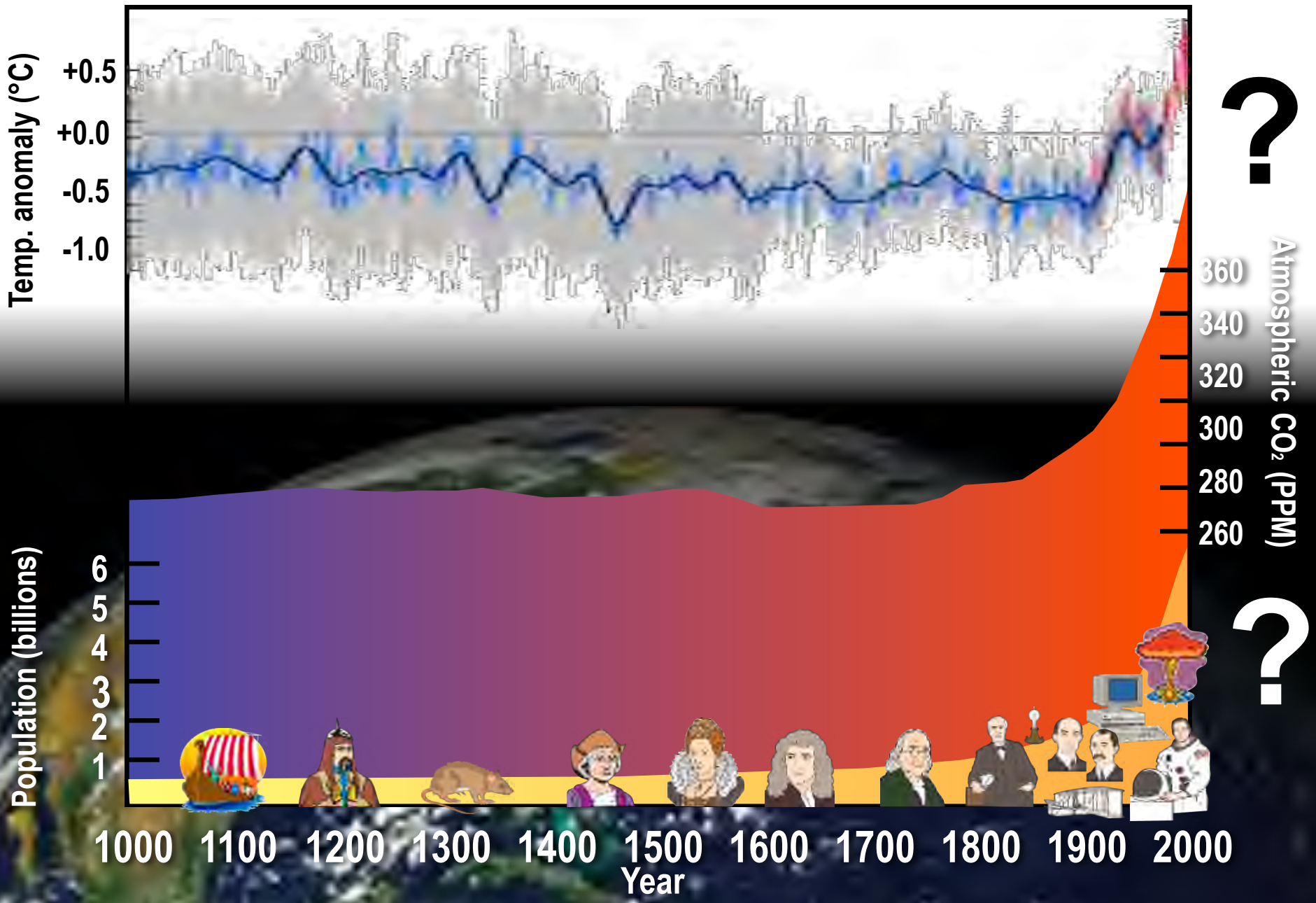
Sustainable population?



?







IPCC predictions www.net.org

Mass extinction (>40% known spp),
Sea level rise...

Food?

~30% wetlands flooded,
freshwater, Islands

Food?

Stress on ecosystems
(Population 9 billion)

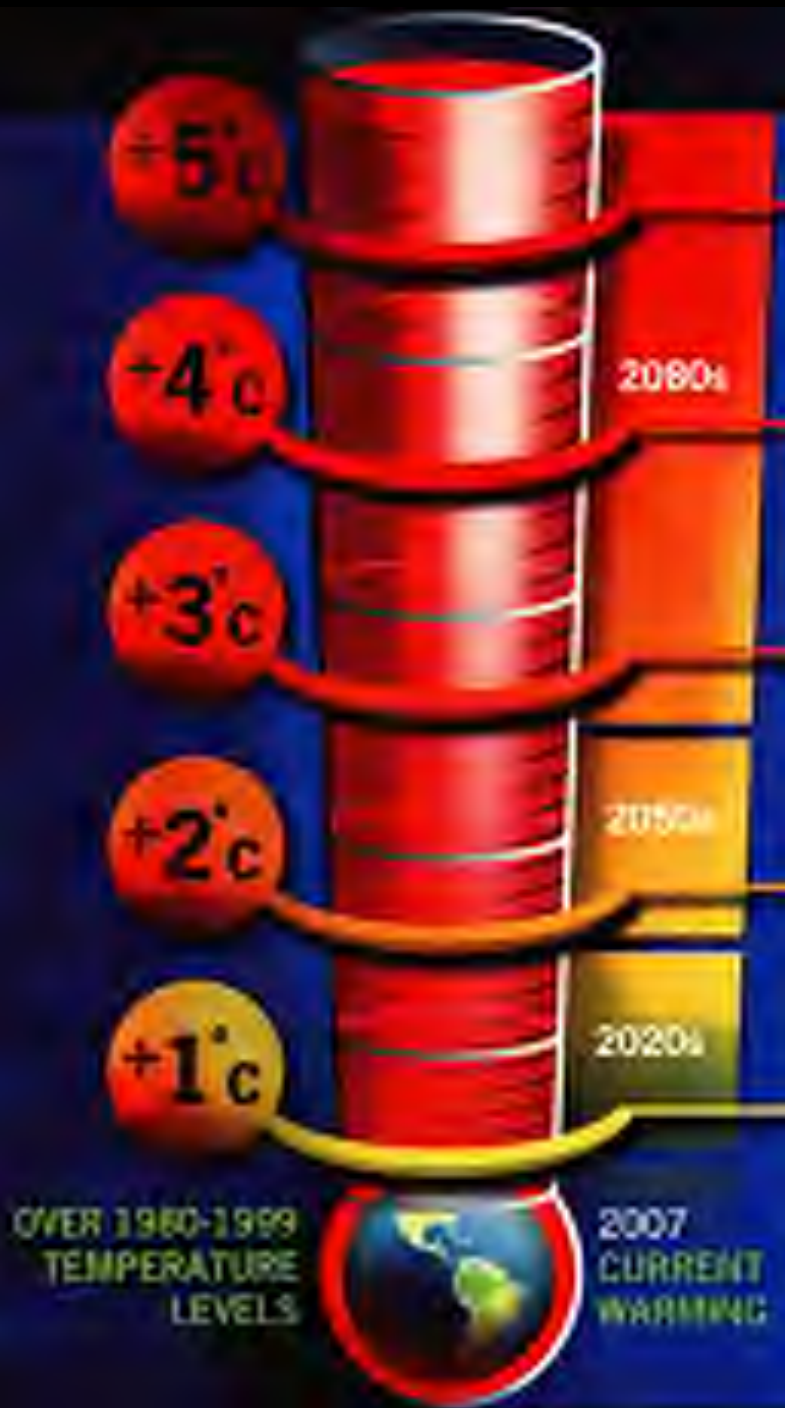
Food?

Extinctions (20-30% known spp),
ocean acidification

Food?

} Temp rise 0.7°C
Weather patterns, wildfires,
floods/droughts

T. Root, Stanford





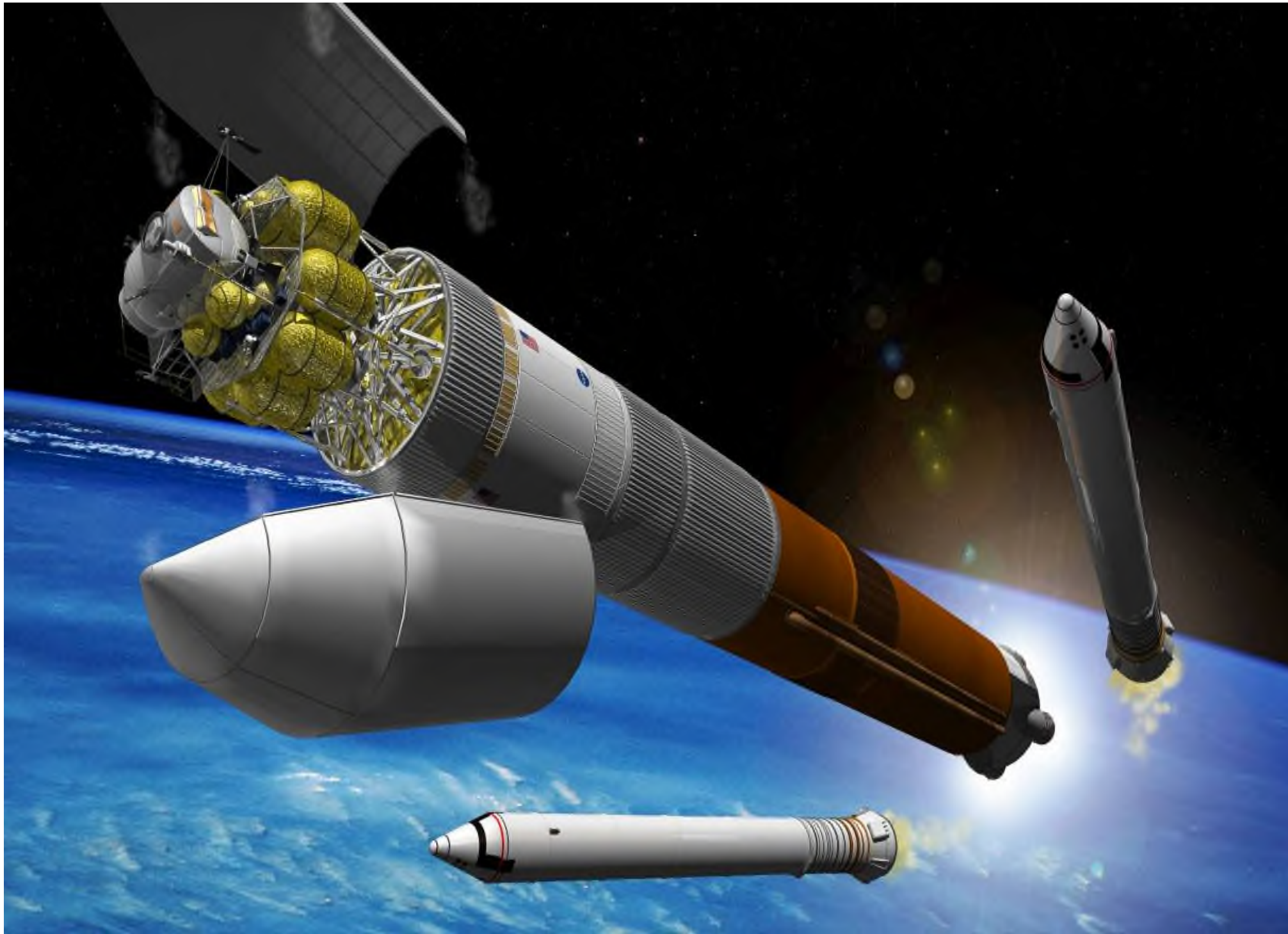
Sustainability?

Population?

Affluence?

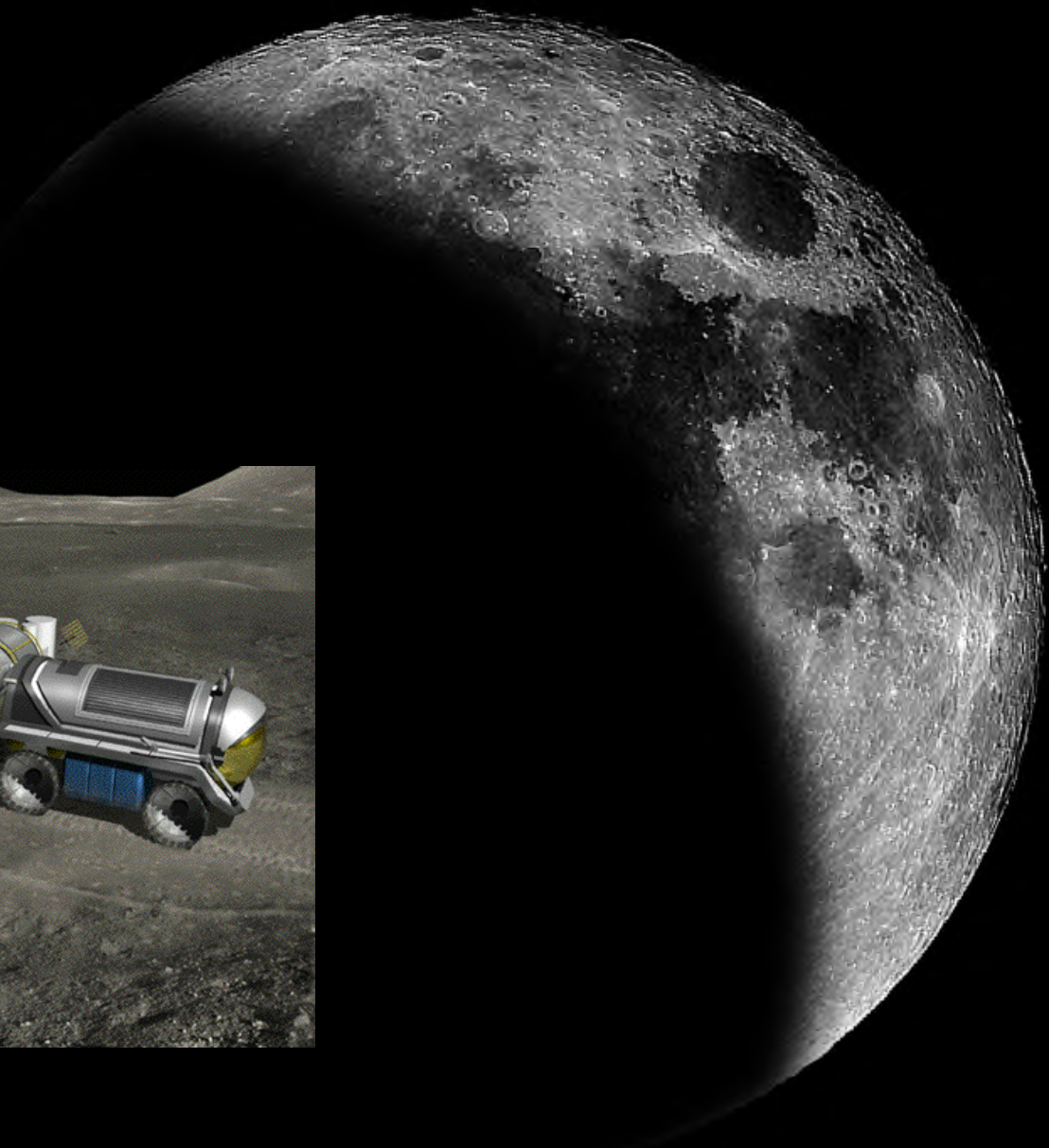
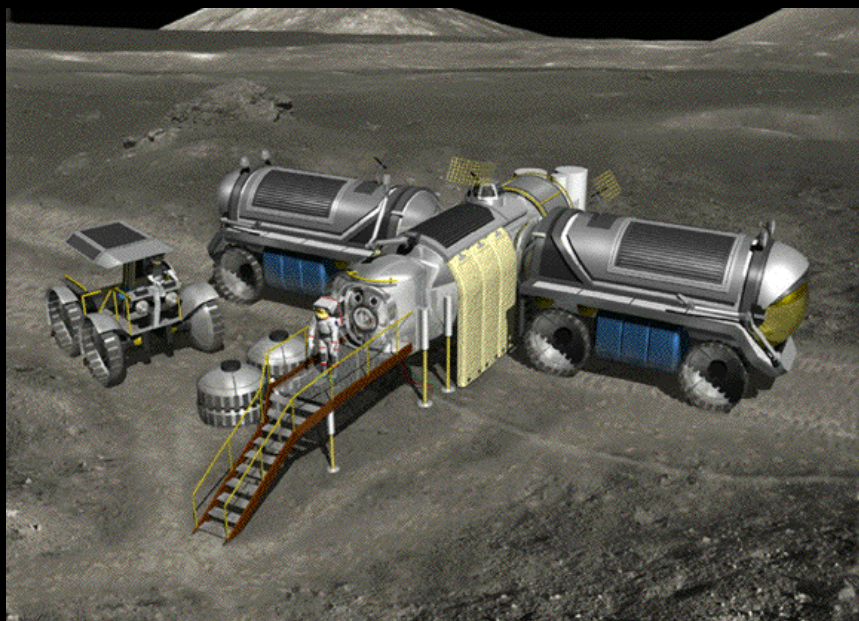
Species diversity?

Technology?









First flight test with sustainable biofuels for commercial aviation



First sustainable biofuel flight test in Asia

First North American sustainable biofuel flight test



Scheduled 2009

NASA



Scheduled 2009

Biofuels fly airplanes...

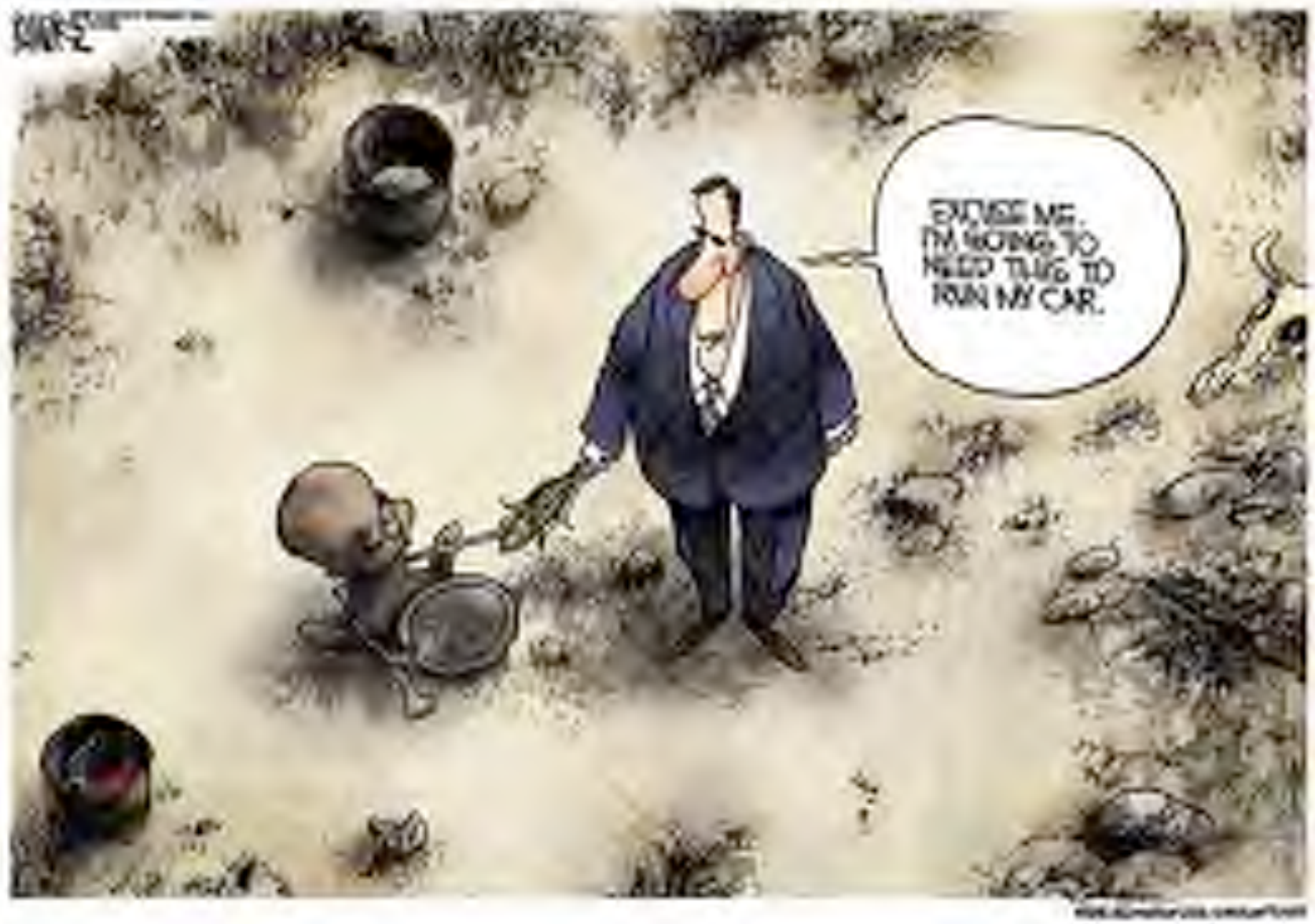
What about Biofuels?

Not use agricultural land

Not use freshwater or fertilizers

Feasible, affordable, scalable, sustainable...

NOW!



How **green** are biofuels?

	Corn	Sugar Cane	Switch Grass
Product			
GHG output*			
Water			
Fertilizer			
Pesticide			
Energy			
US crop land/ half demand			

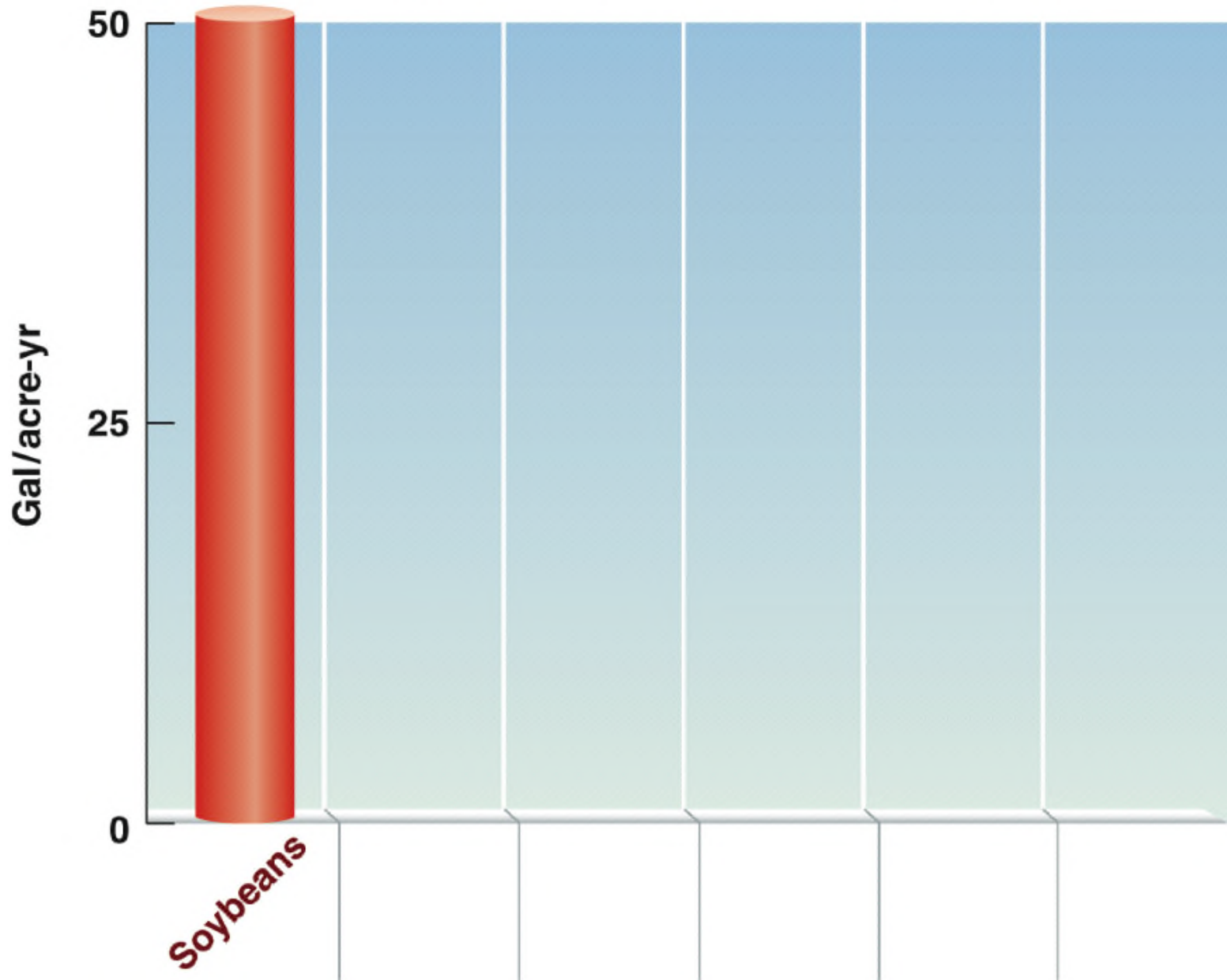
*CO₂ kg/MJ: Growing, harvesting, refining, burning fuel (cf., gas=94)

The problem with biodiesel...

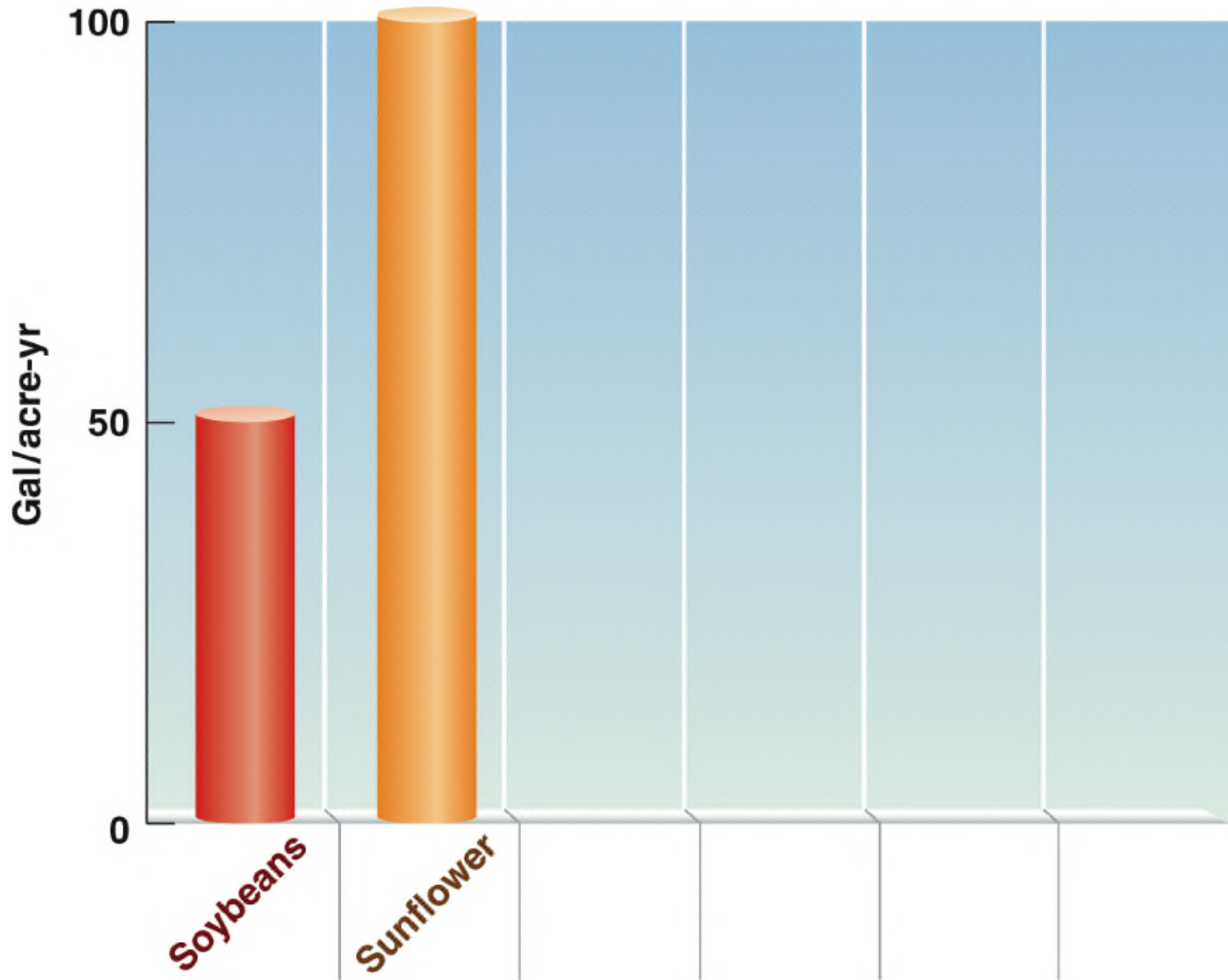
	Wood Residue	Soybeans	Rapeseed, Canola
Product	Ethanol, biodiesel	biodiesel	biodiesel
GHG output*	N/A	49	37
Water	low	HIGH	HIGH
Fertilizer	low	low-med	med
Pesticide	low	med	med
Energy	low	med-low	med-low
US crop land/ half demand	150 -250%	180-240%	30%

*CO₂ kg/MJ: Growing, harvesting, refining, burning fuel (cf., Diesel=83)

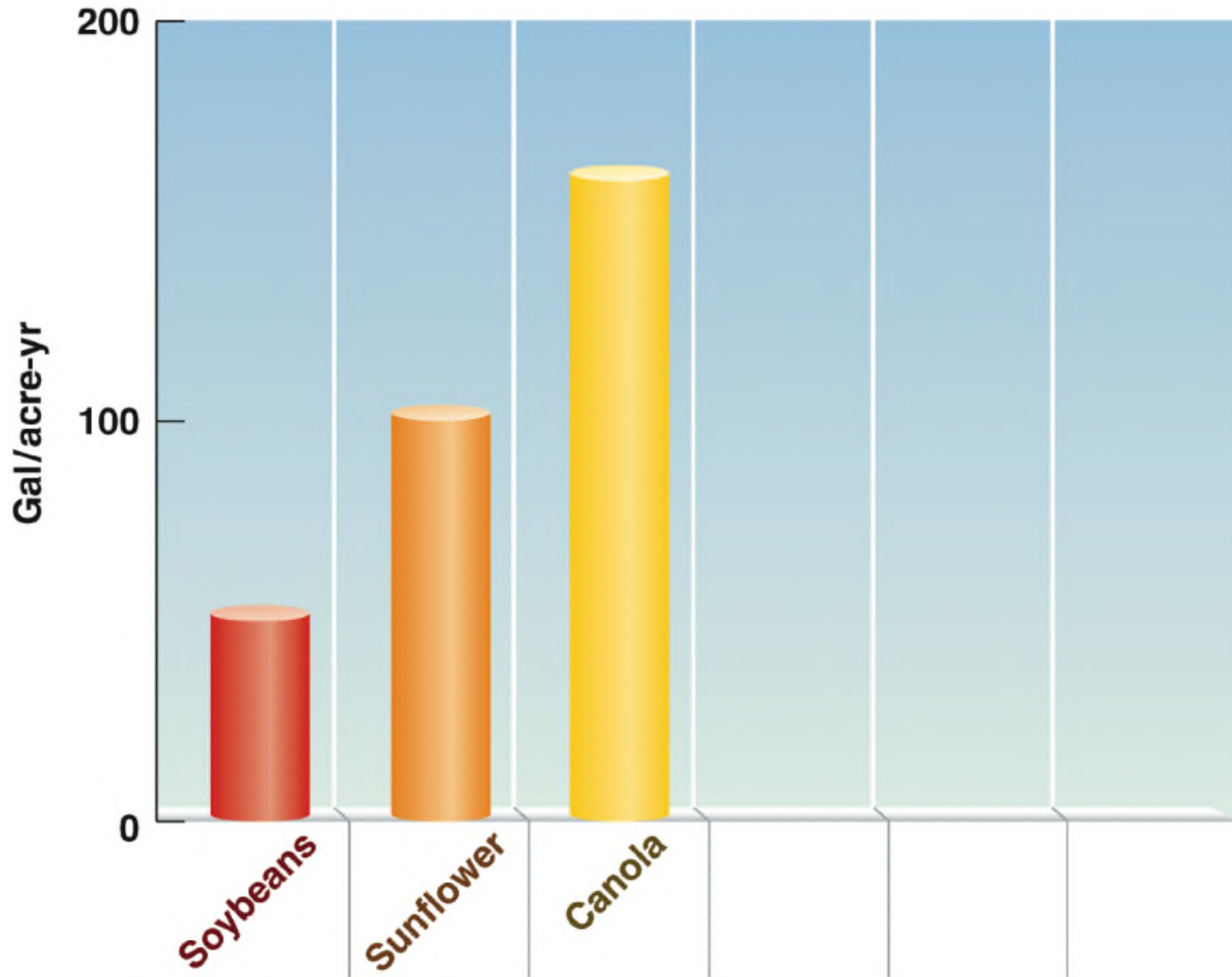
BIODIESEL CROPS AND PRODUCTION



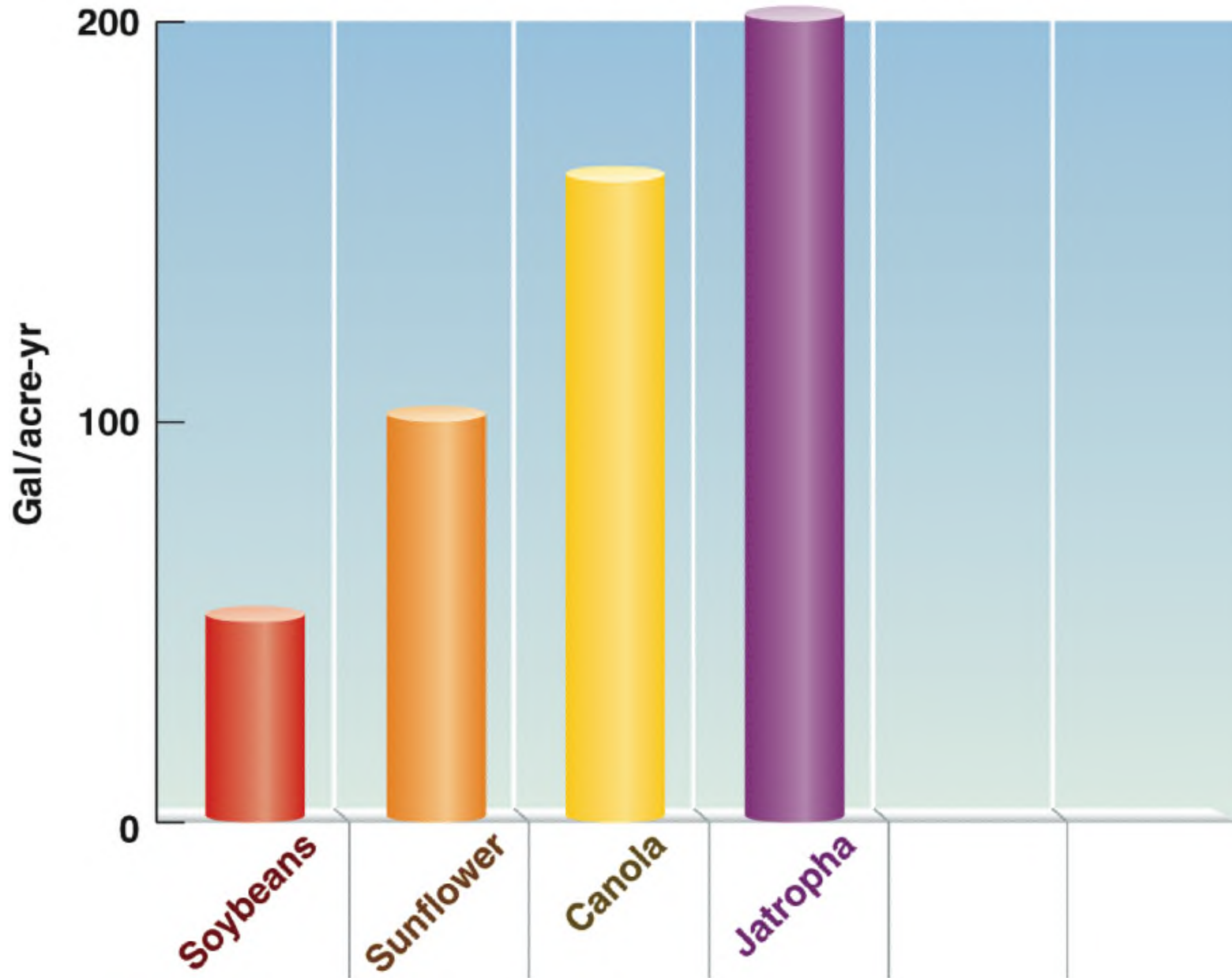
BIODIESEL CROPS AND PRODUCTION



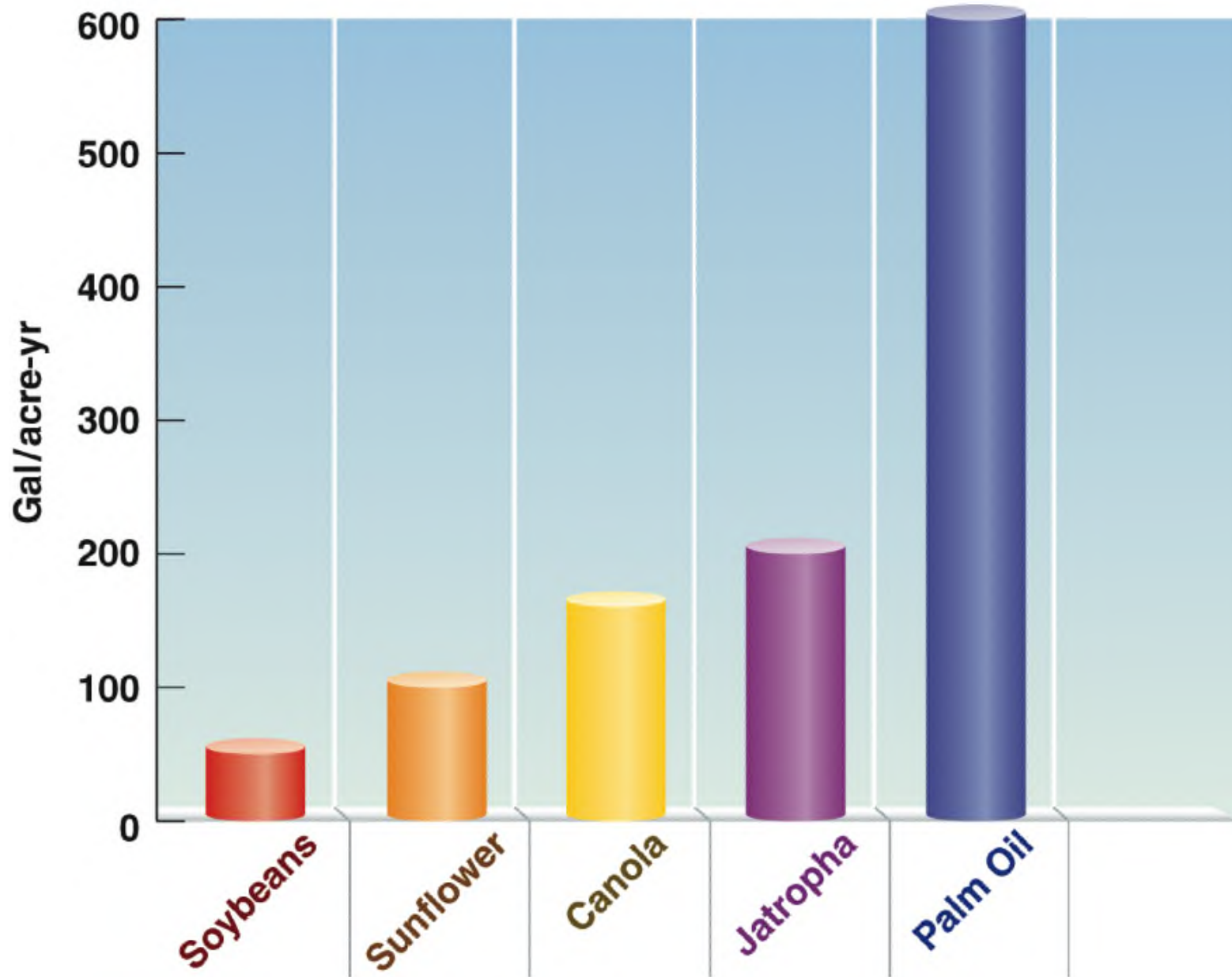
BIODIESEL CROPS AND PRODUCTION



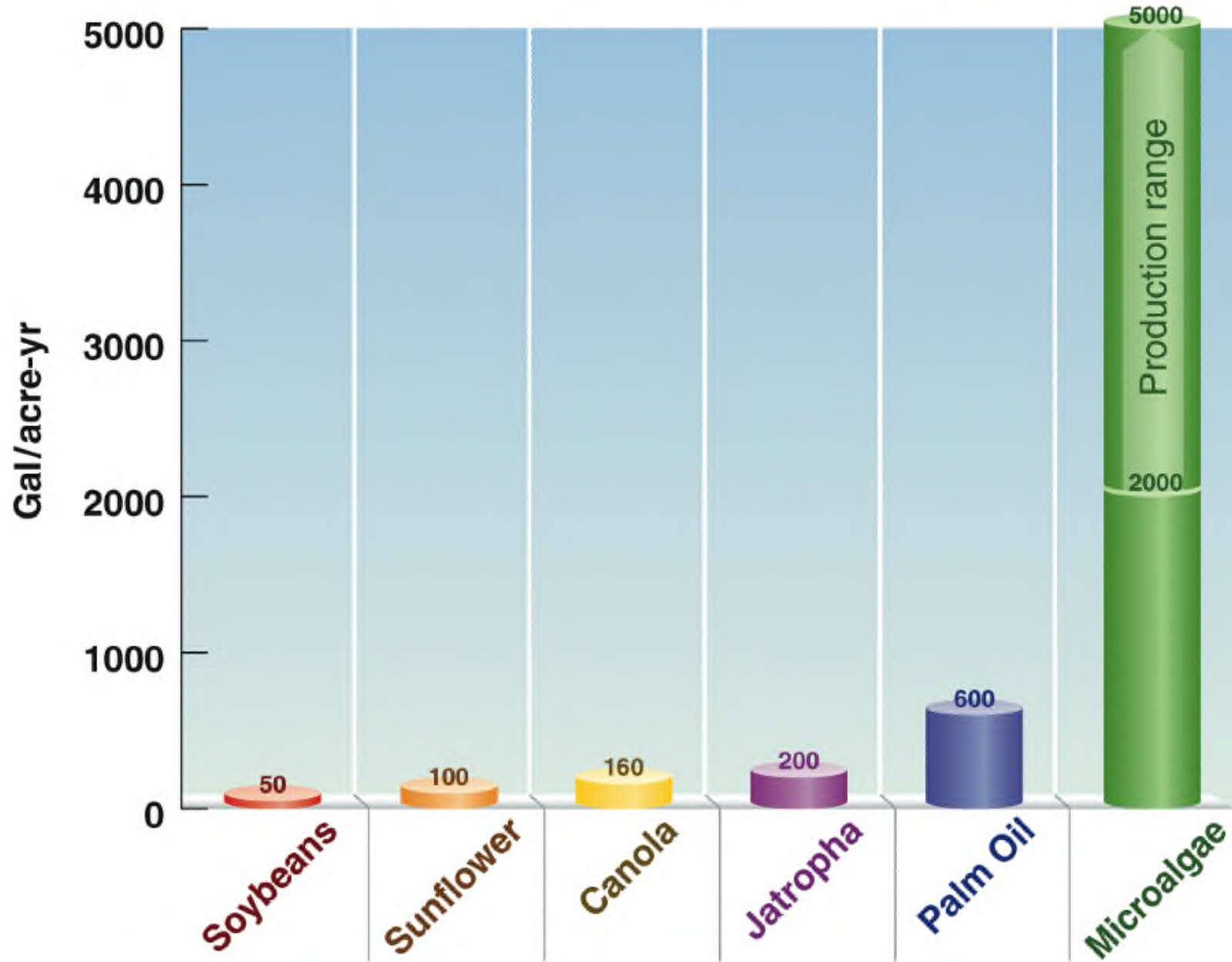
BIODIESEL CROPS AND PRODUCTION



BIODIESEL CROPS AND PRODUCTION



BIODIESEL CROPS AND PRODUCTION



Botryococcus braunii

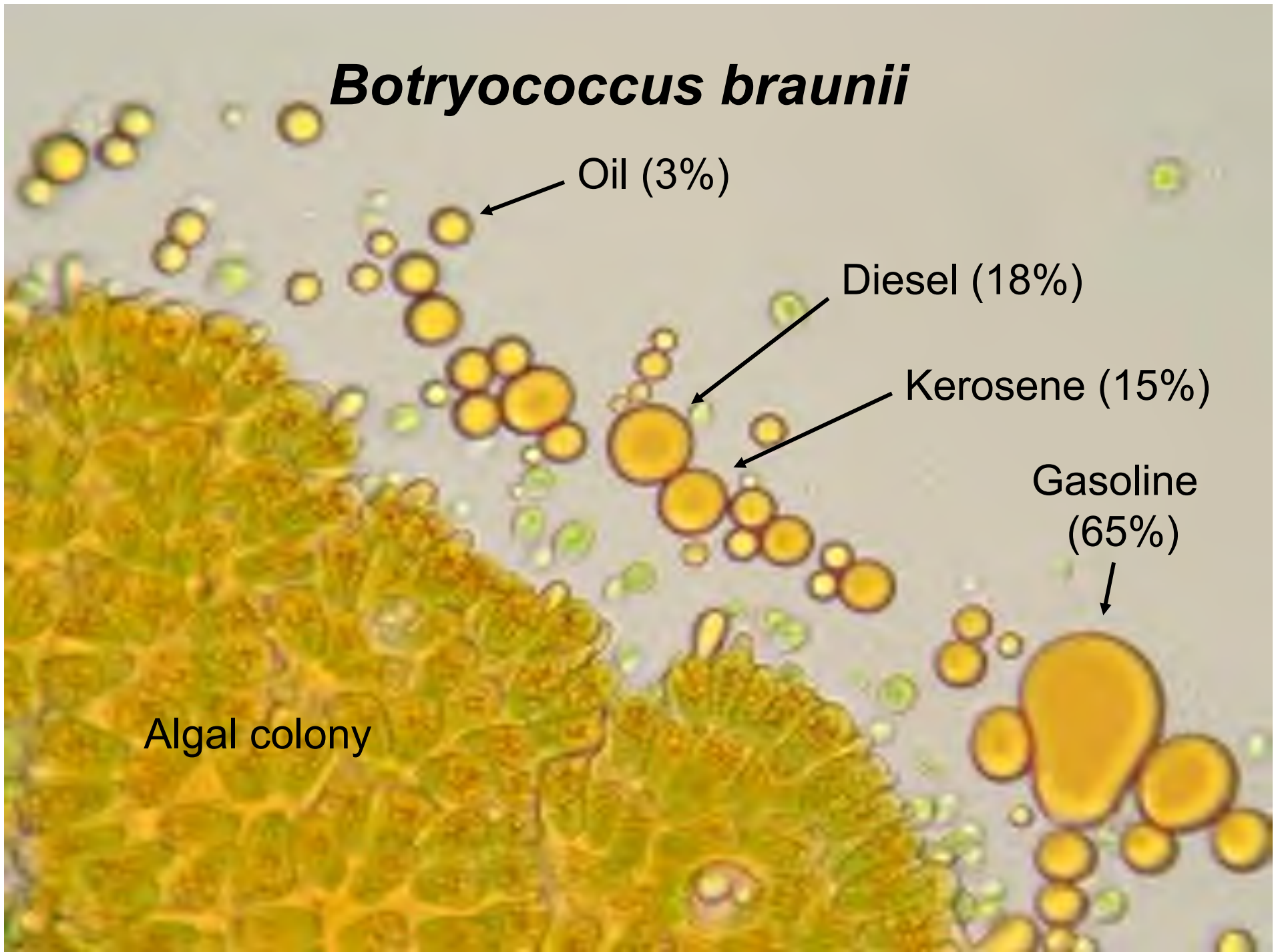
Oil (3%)

Diesel (18%)

Kerosene (15%)

Gasoline (65%)

Algal colony

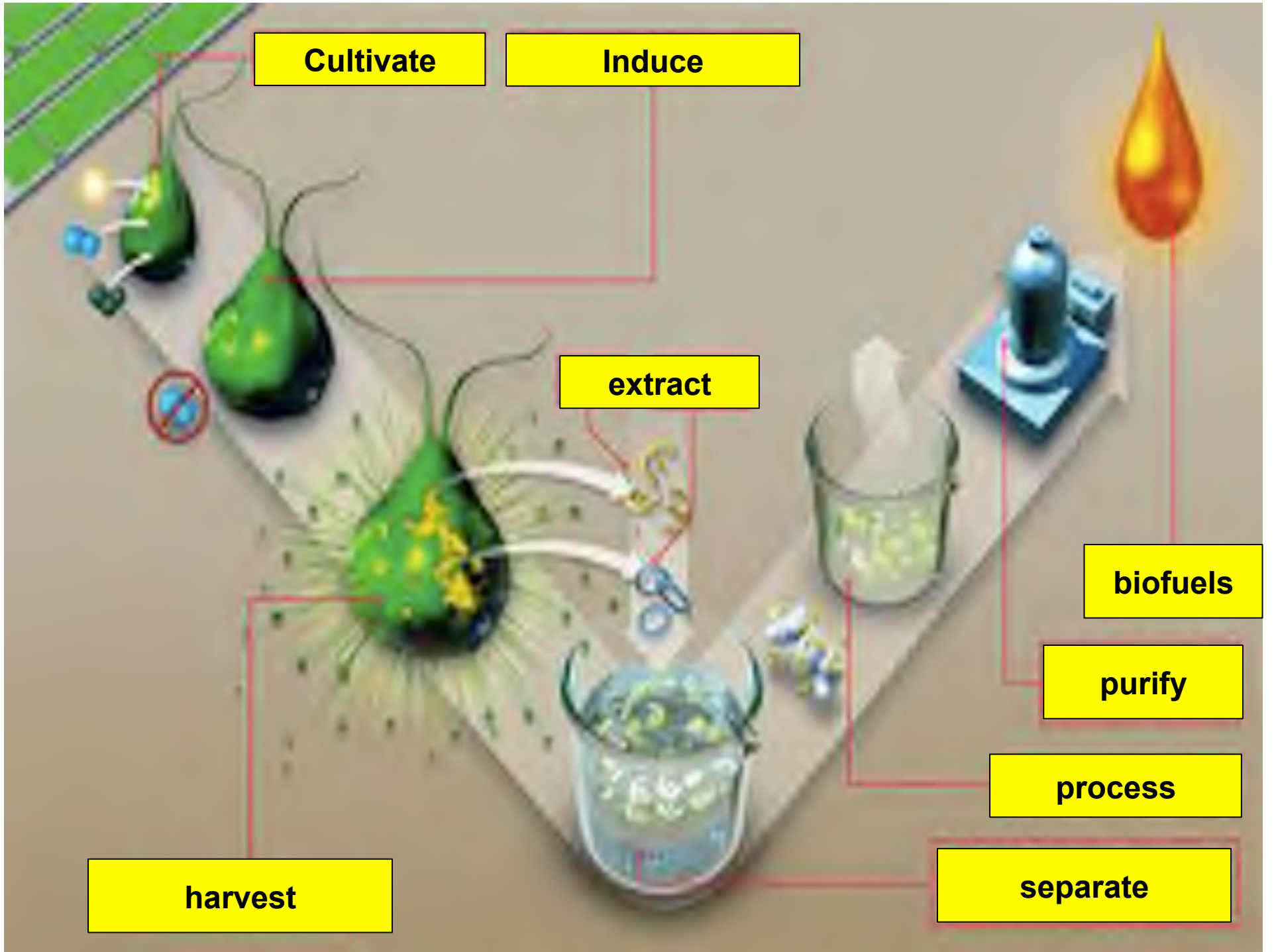




Biodiesel crops and production:!

Plant	Gal/acre-yr	Barrels/yr
Soybeans	50	>10,000,000
Sunflower	100	> 1,000,000
Canola	160	>10,000,000
Jatropha	200?	some, not much
Palm Oil	600	>10,000,000
Microalgae	2,000 to 5,000	~0.1

from: Benemann 2009. Algae Biomass Summit !



**There are challenges
growing
algae on land...**

**Open circulating ponds
(raceways)**

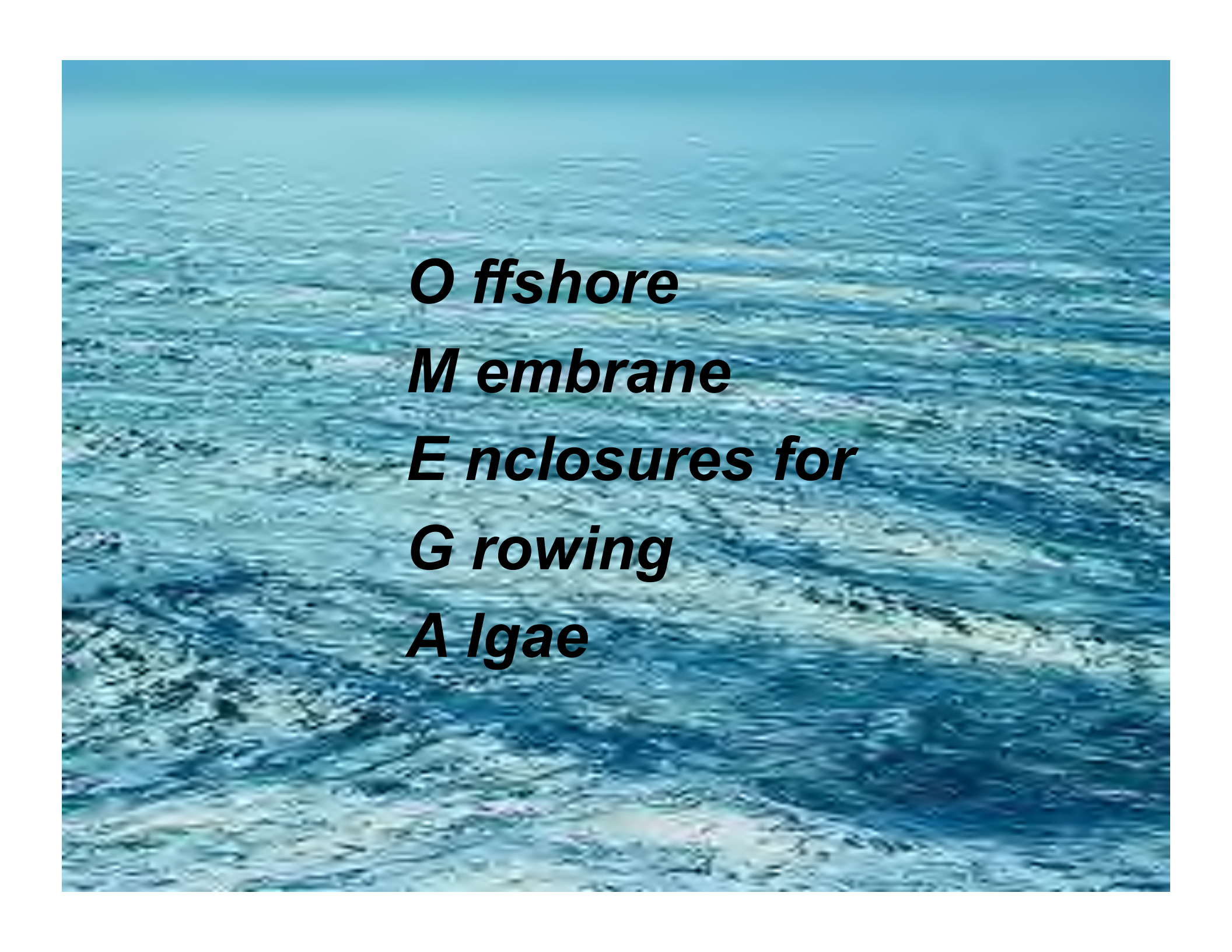


**Closed photobioreactors
(PBRs)**



***What about growing algae
in the ocean?***

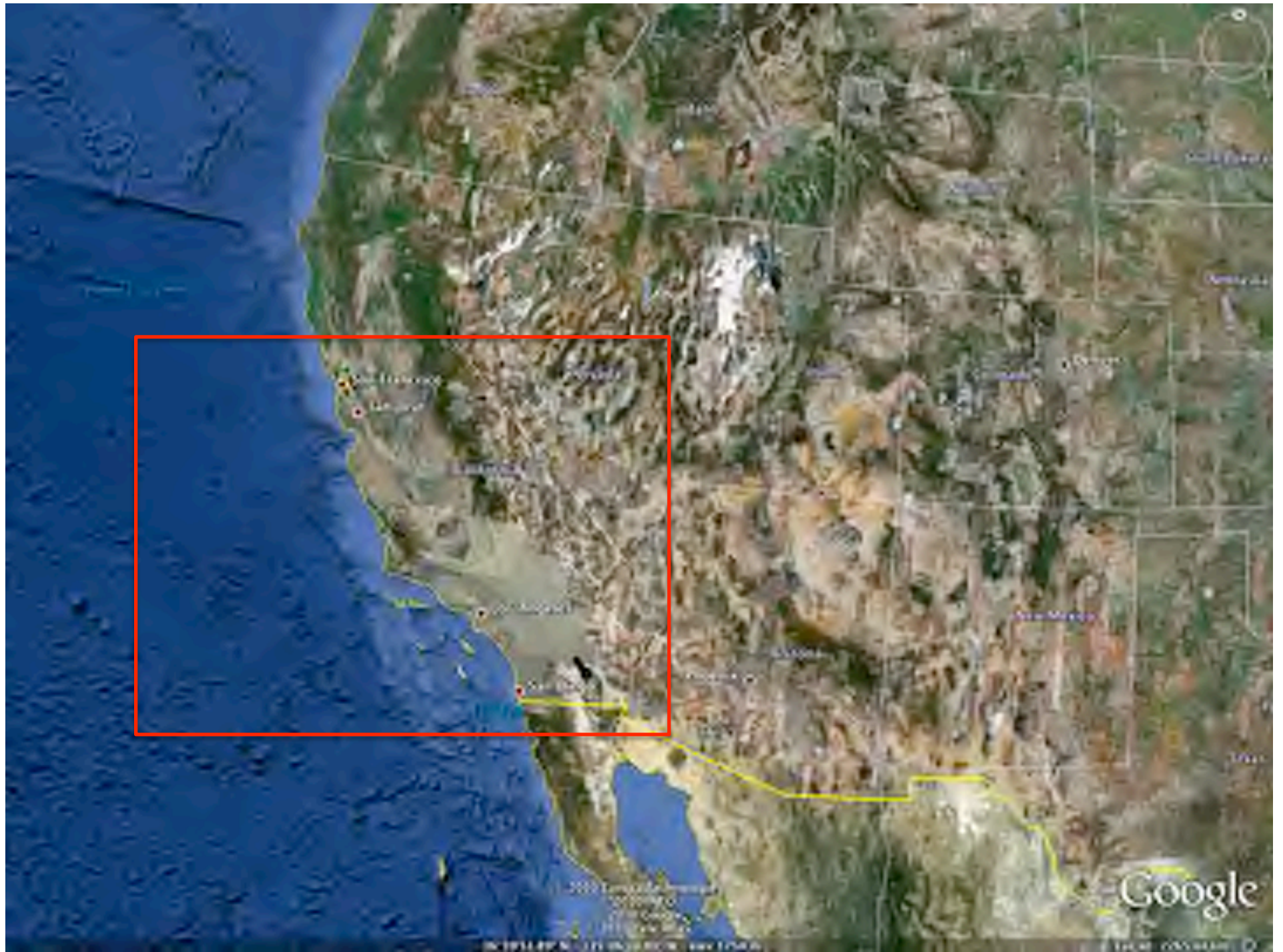


An aerial photograph of a large body of water, likely a lake or a wide river, with a winding path or channel cutting through it. The water is a deep blue color, and the path is a lighter, sandy or silty color. The text is overlaid on the right side of the image.

O ffshore
M embrane
E nclosures for
G rowing
A lgae









San Francisco,
Southeast WPCP 67 MGD

San Jose Santa Clara Water 112.7 MGD

Santa Cruz 9.1 MGD

Monterey Regional 29.6 MGD

**GRAND TOTAL
= 1.87 BILLION
GAL/DAY**

Santa Barbara 8.5 MGD

Hyperion (L.A. City) 425 MGD

Joint Water Pollution
Control Plant 320 MGD

Orange County 320 MGD

Point Loma 170 MGD

MGD = Million Gal/Day

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Data SIO, NOAA, U.S. Navy, NGA, GEBCO

15°17'09.47" N 120°22'48.22" W elev. 416 m

Google

1:60,000 46.142 km

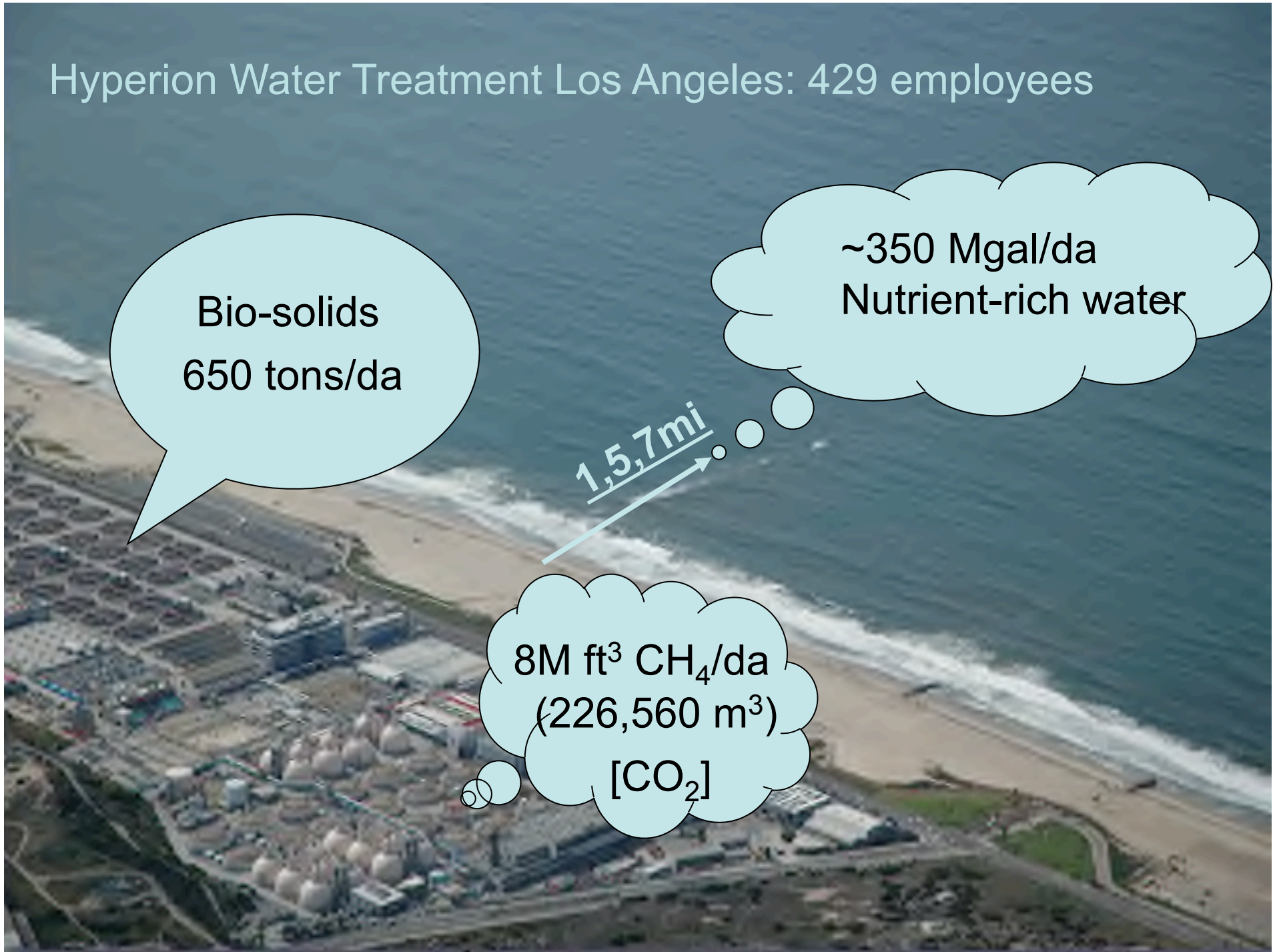
Hyperion Water Treatment Los Angeles: 429 employees

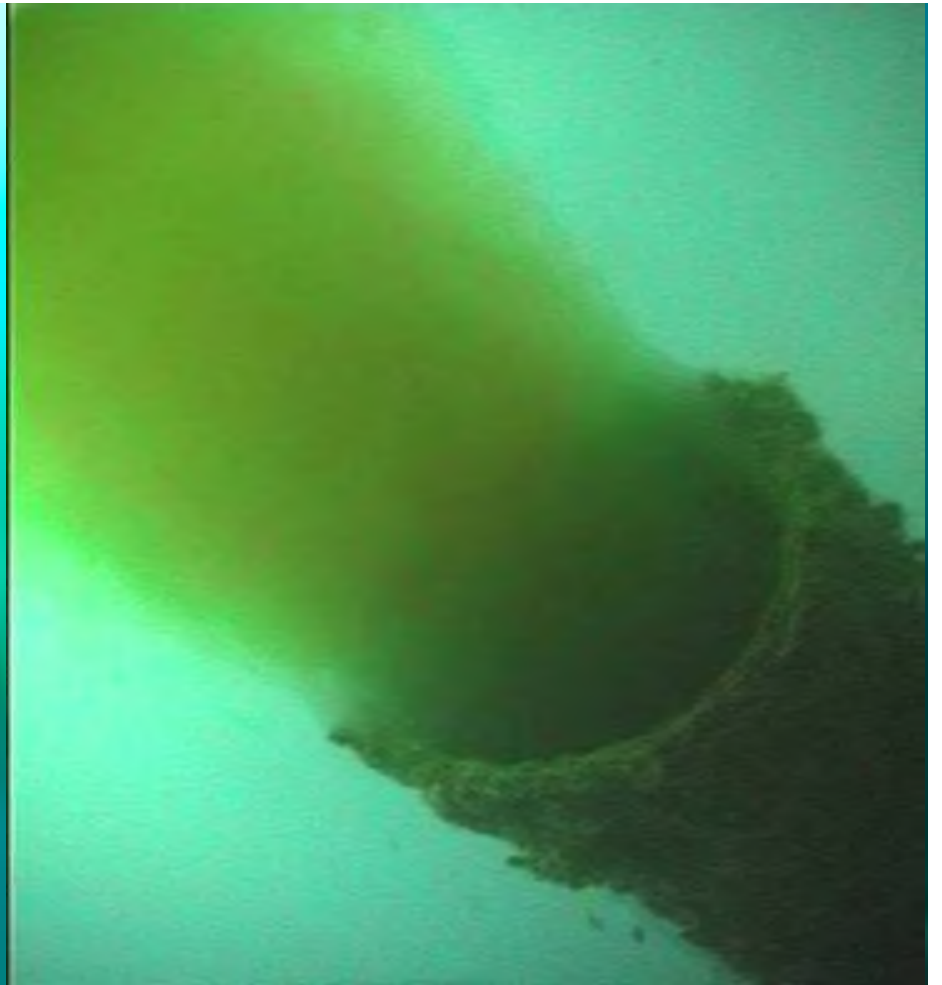
Bio-solids
650 tons/da

~350 Mgal/da
Nutrient-rich water

1,5,7mi

8M ft³ CH₄/da
(226,560 m³)
[CO₂]





OMEGA System

Ocean
(3.5% salt)

Biofuels
Fertilizer
Biochar etc.

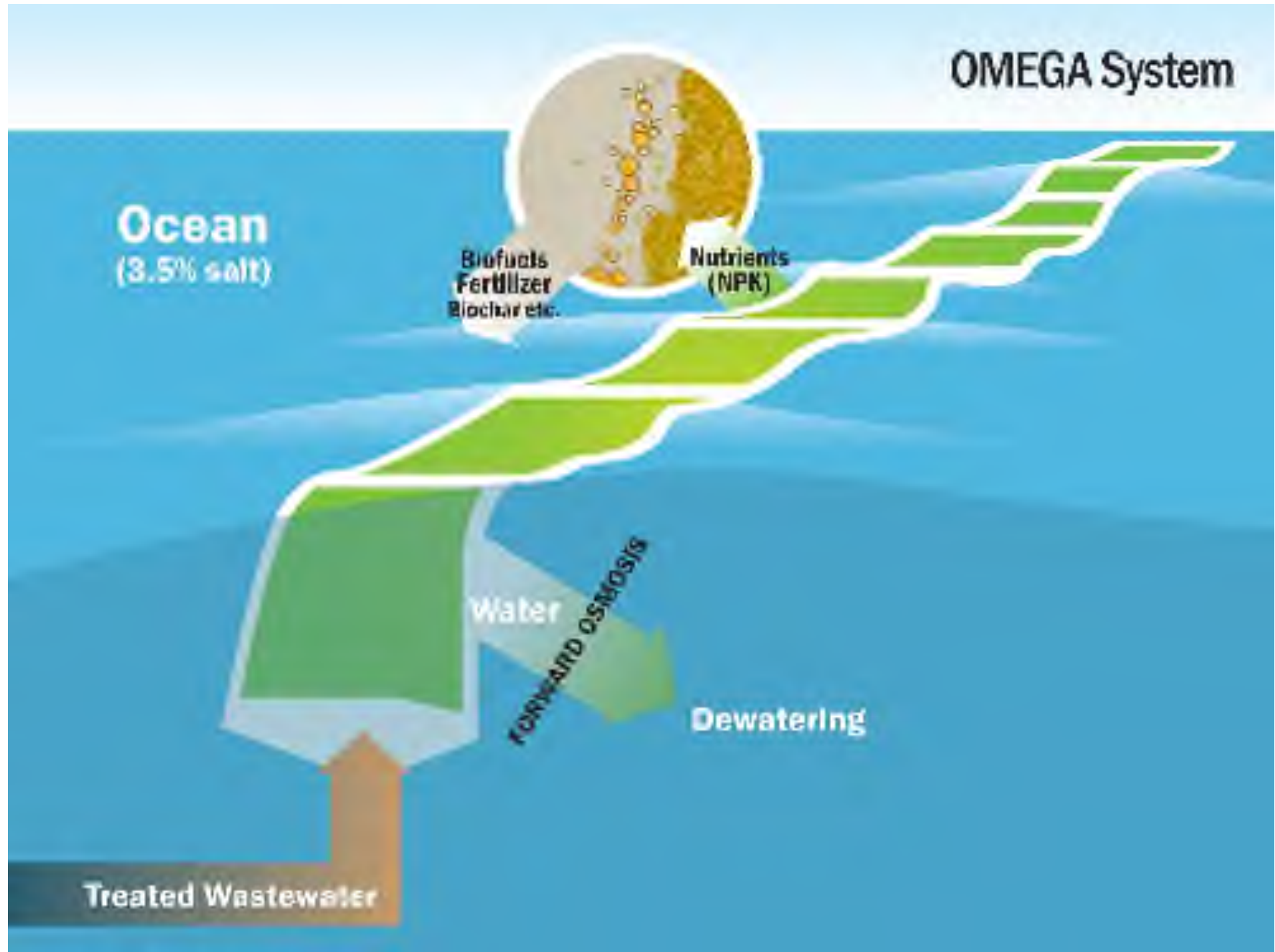
Nutrients
(NPK)

Water

FORWARD OSMOSIS

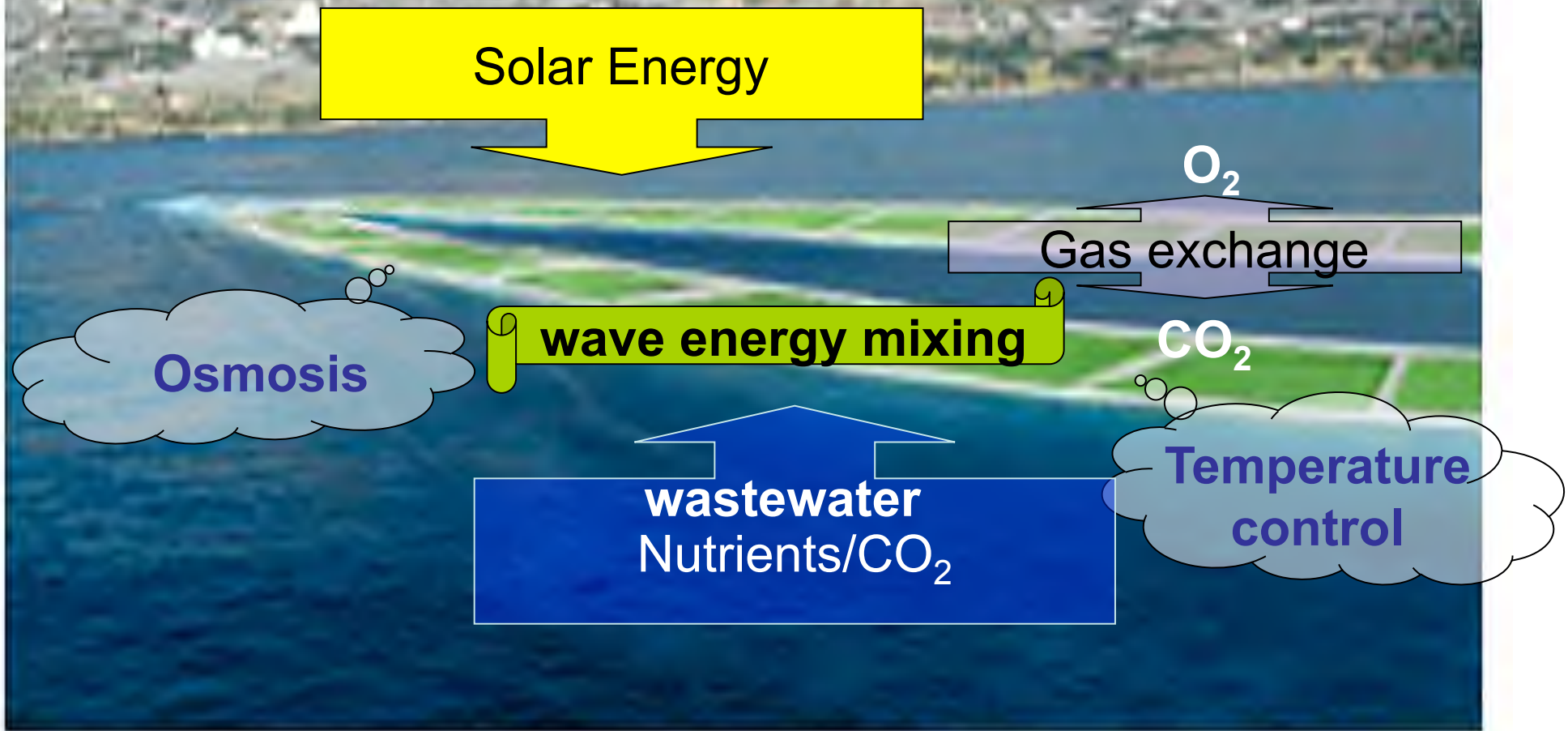
Dewatering

Treated Wastewater





OMEGA



**OMEGA
Benefits?**

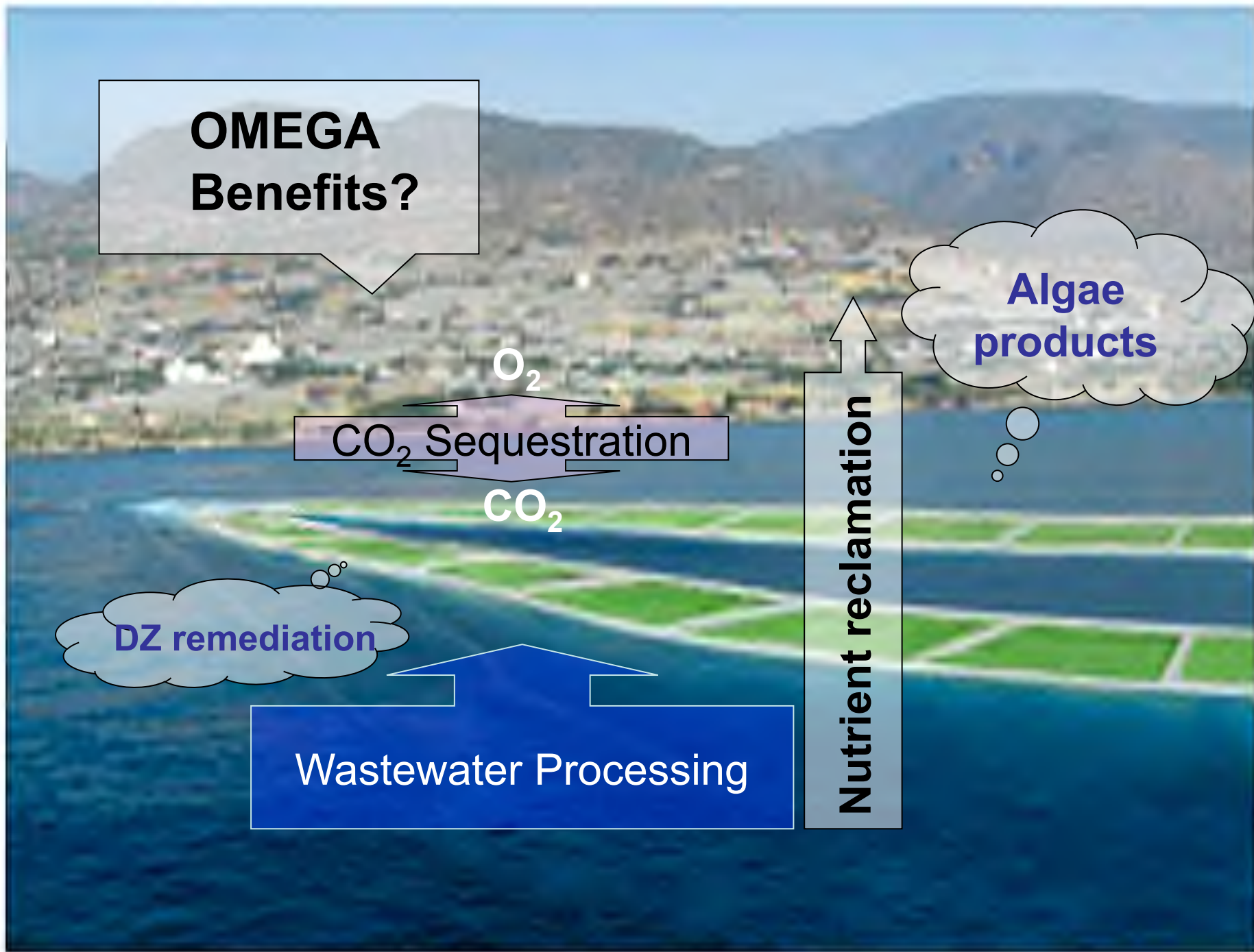
O_2
CO₂ Sequestration
 CO_2

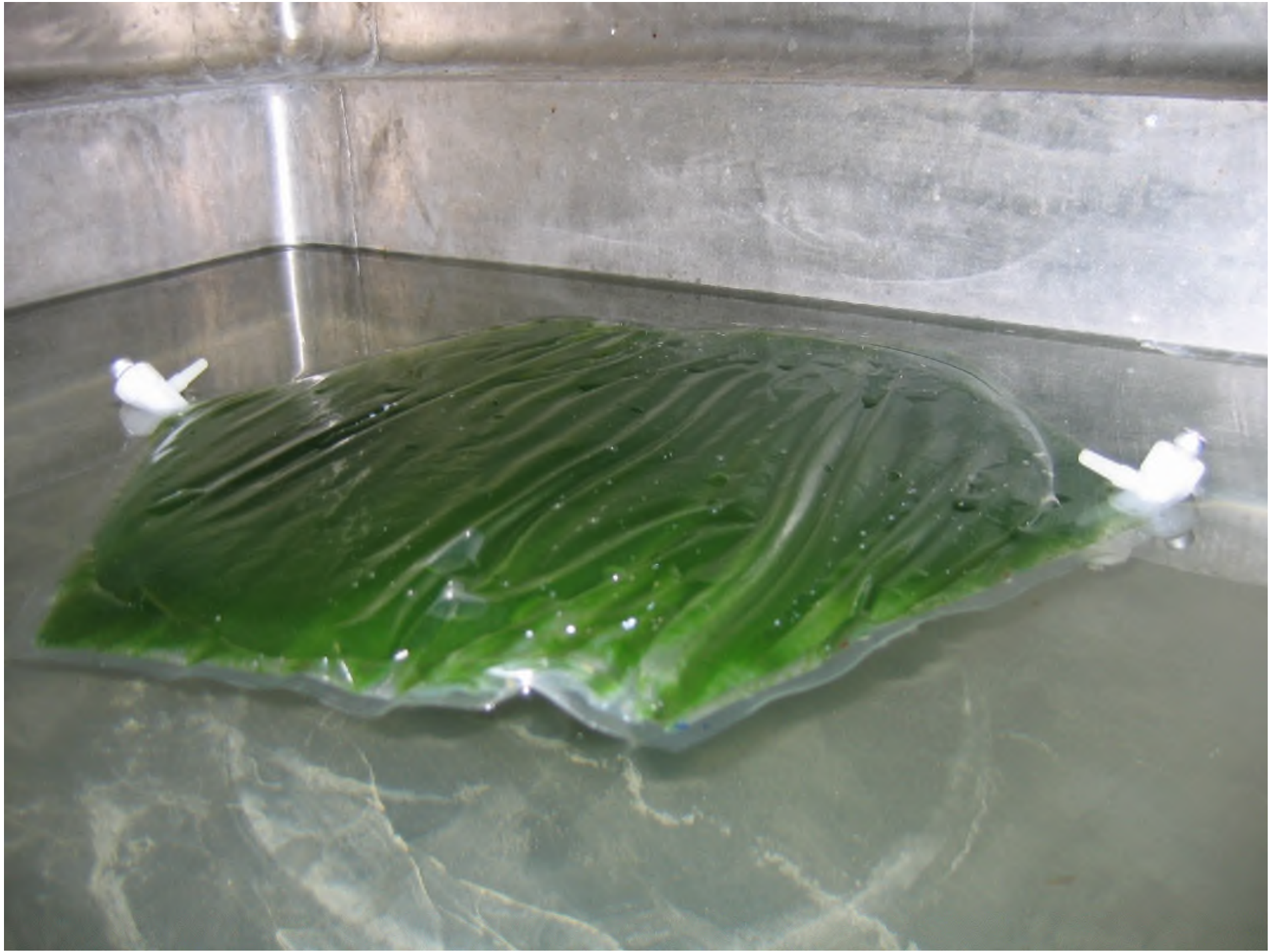
DZ remediation

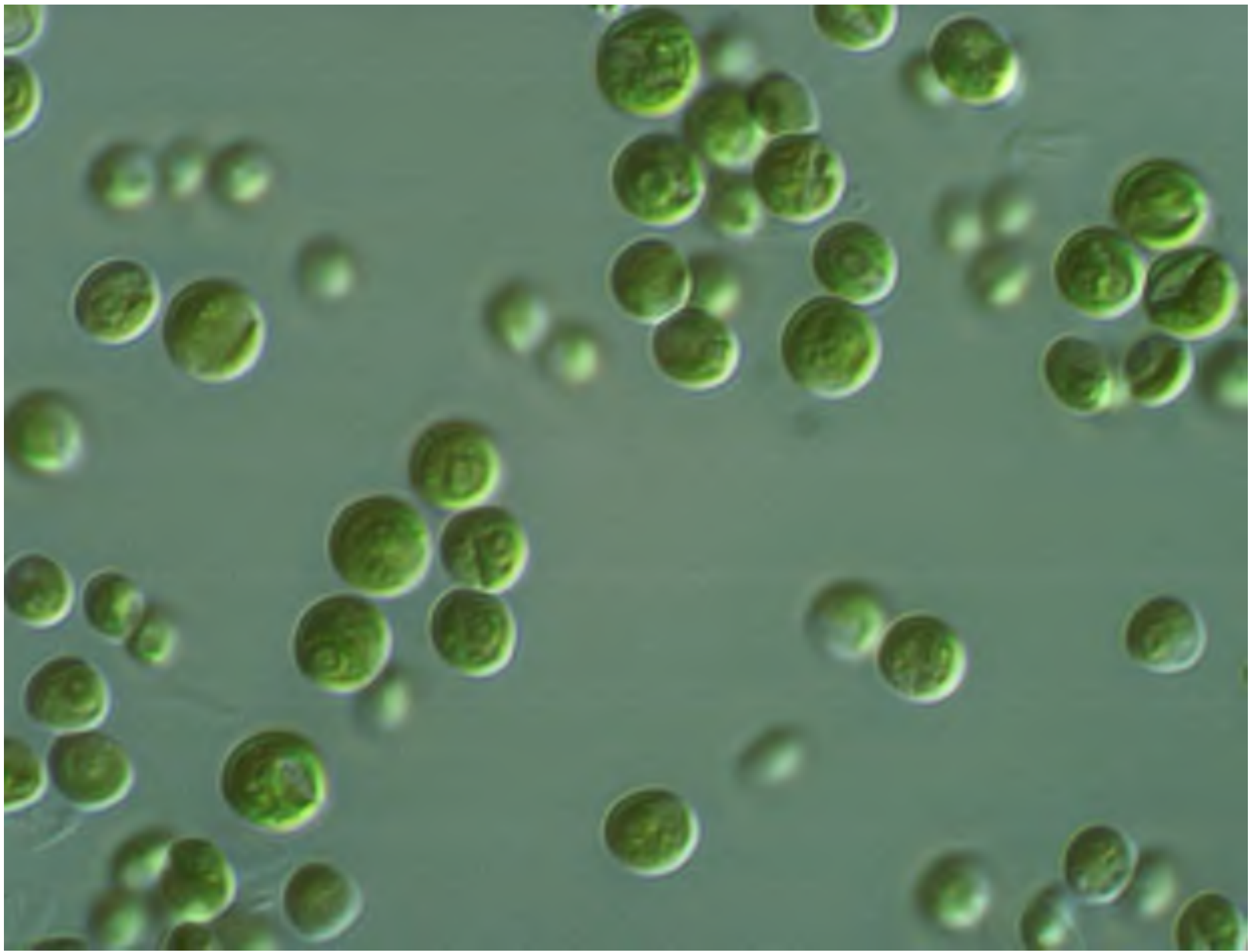
Wastewater Processing

Nutrient reclamation

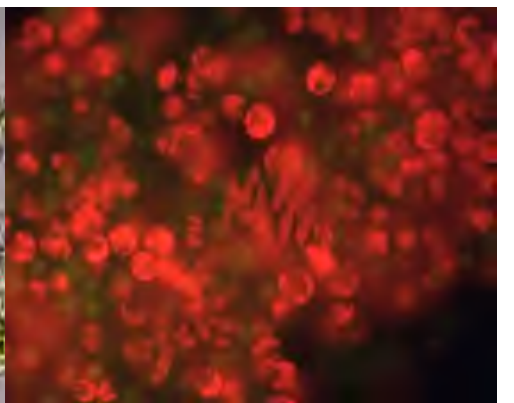
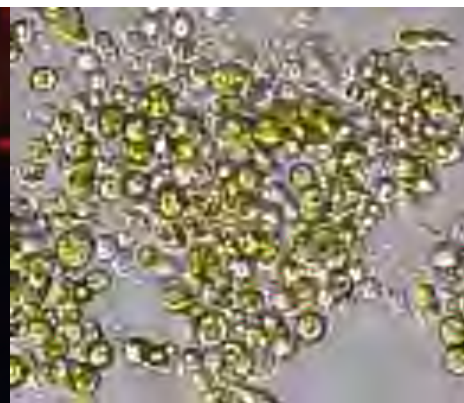
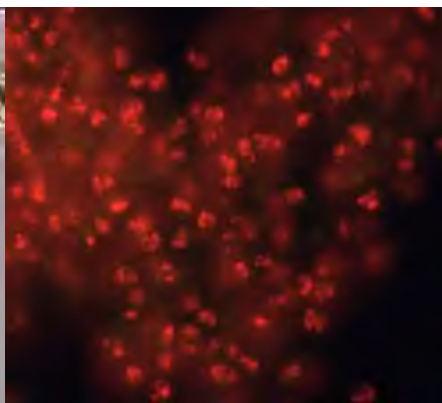
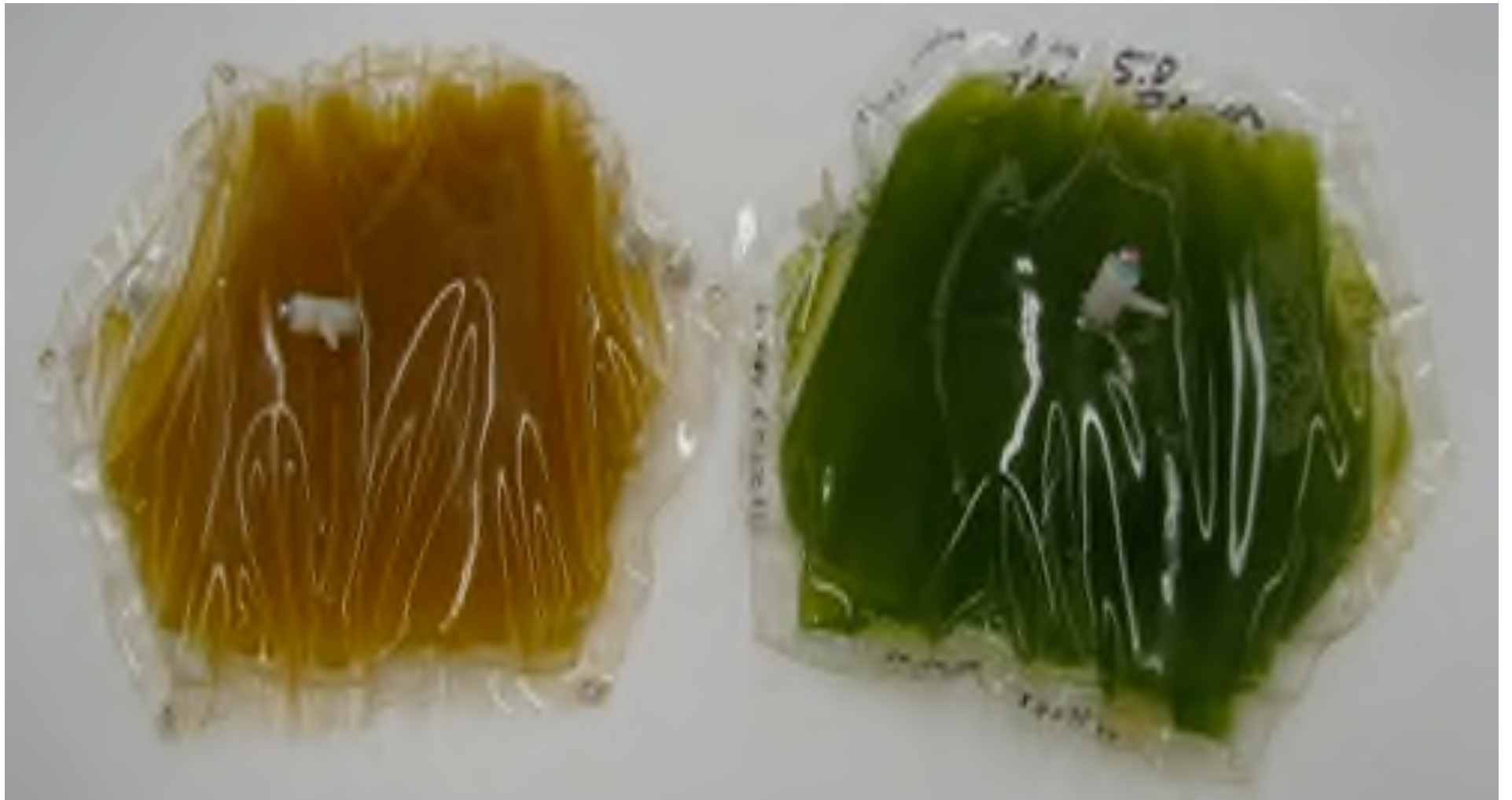
**Algae
products**



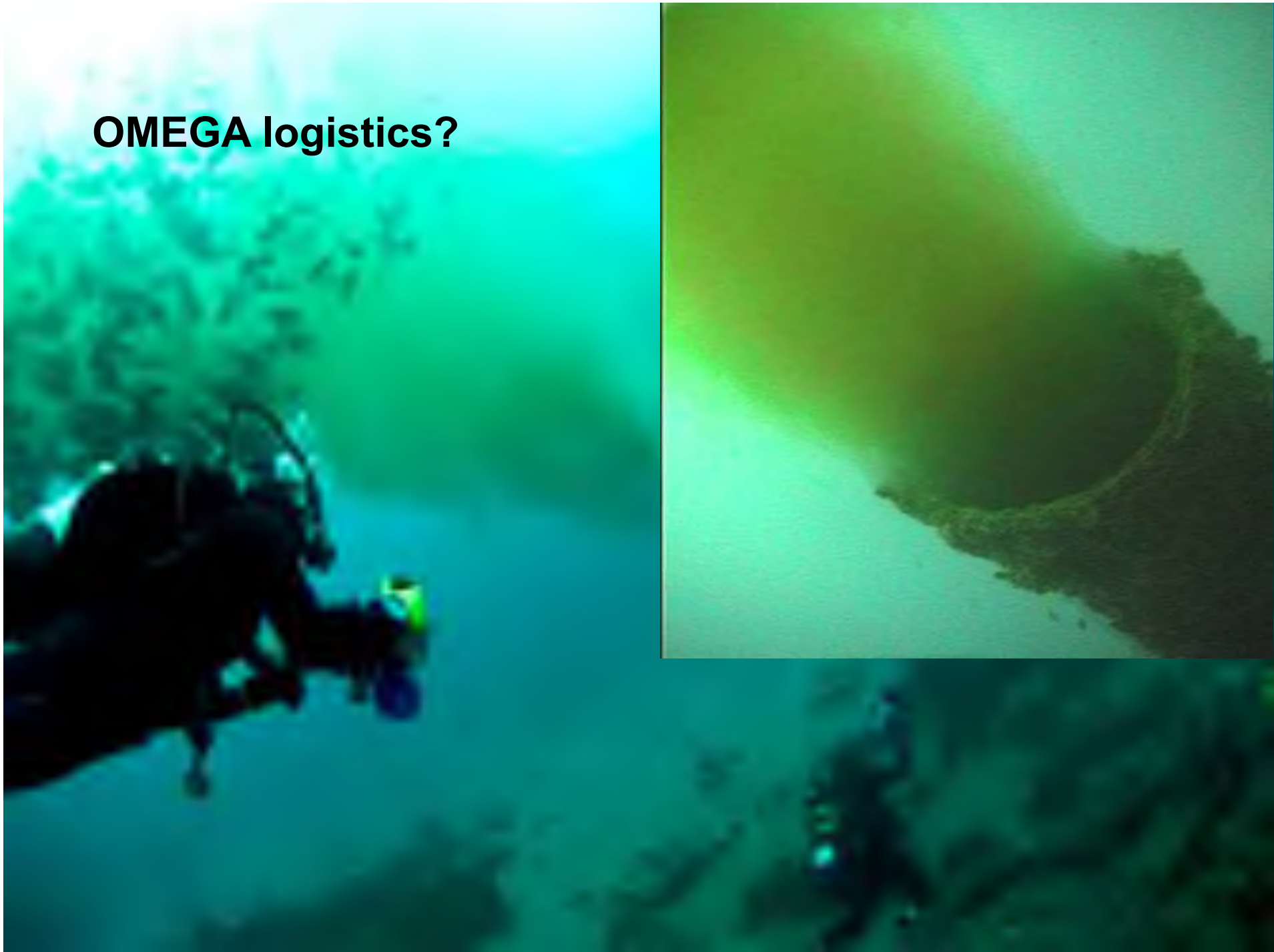


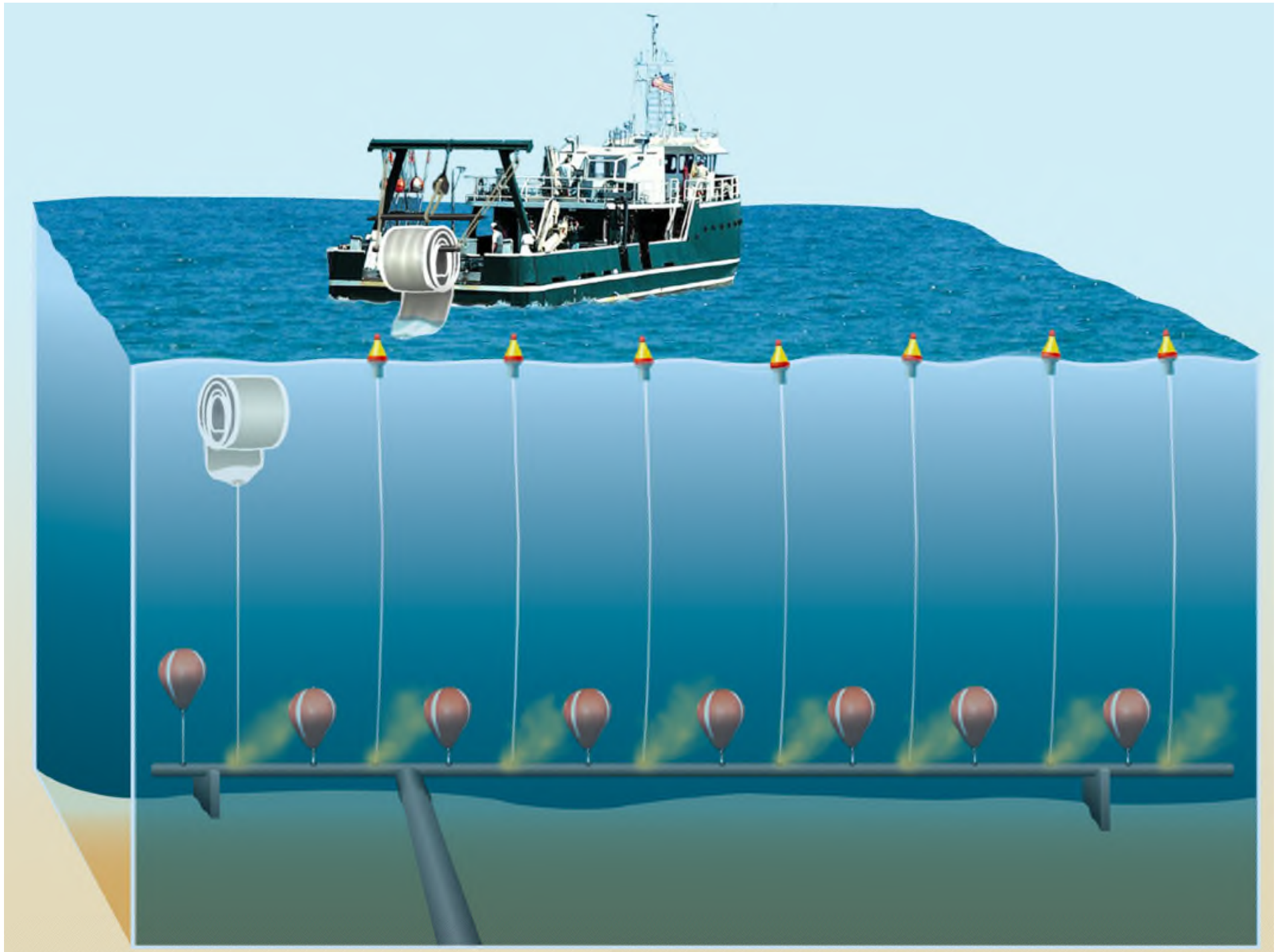


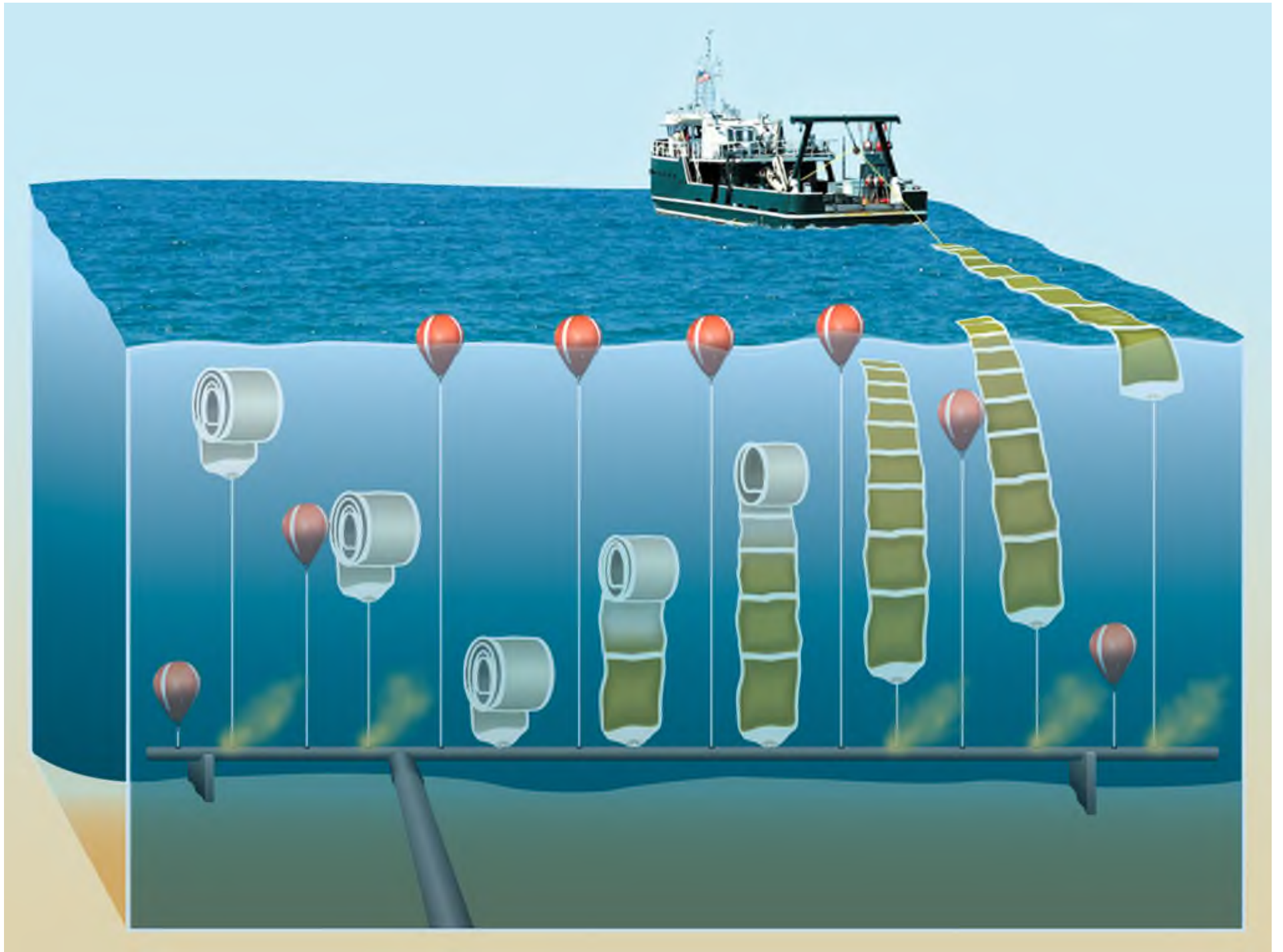


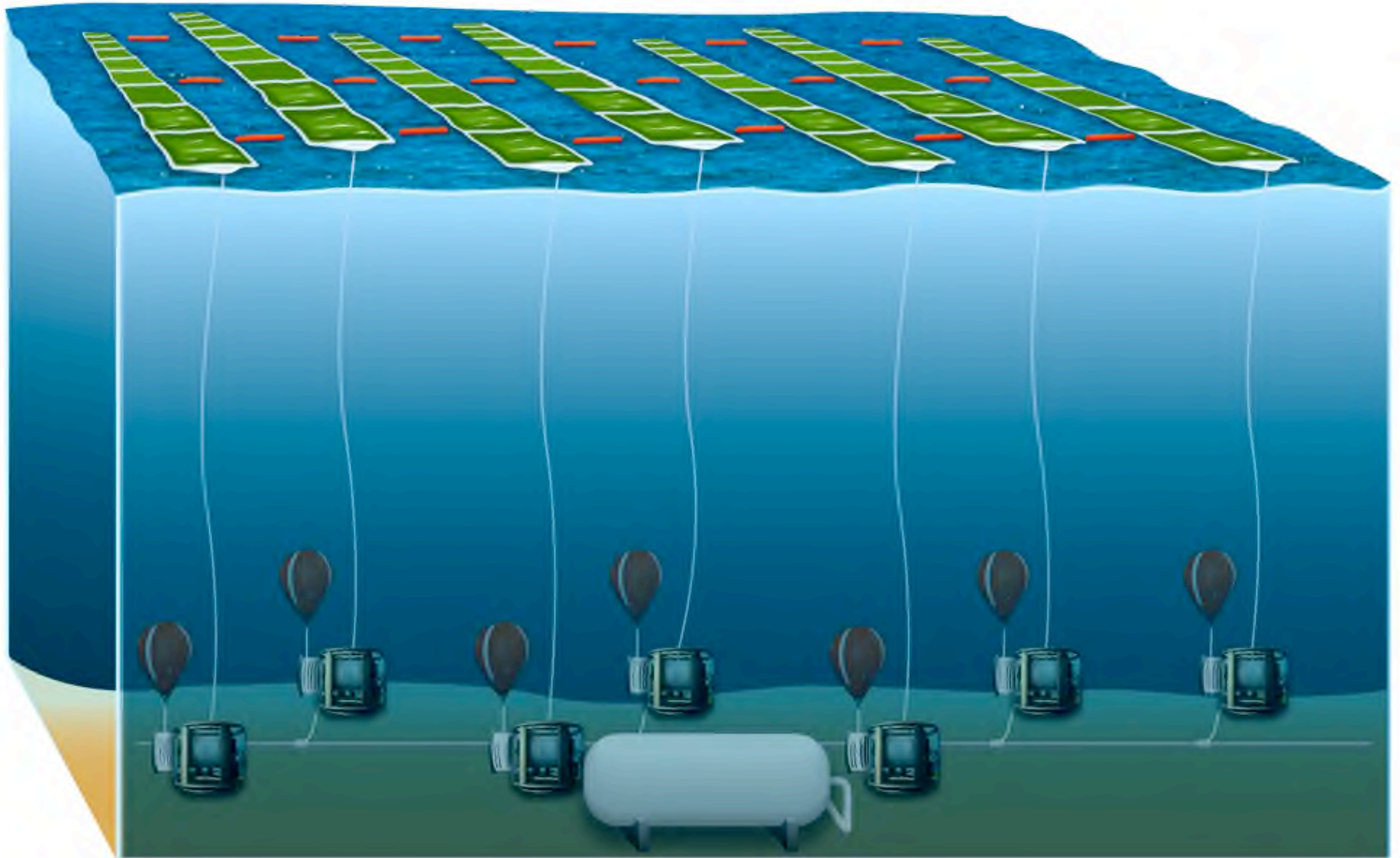
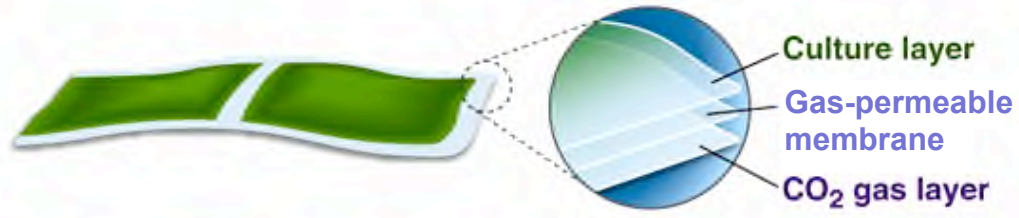


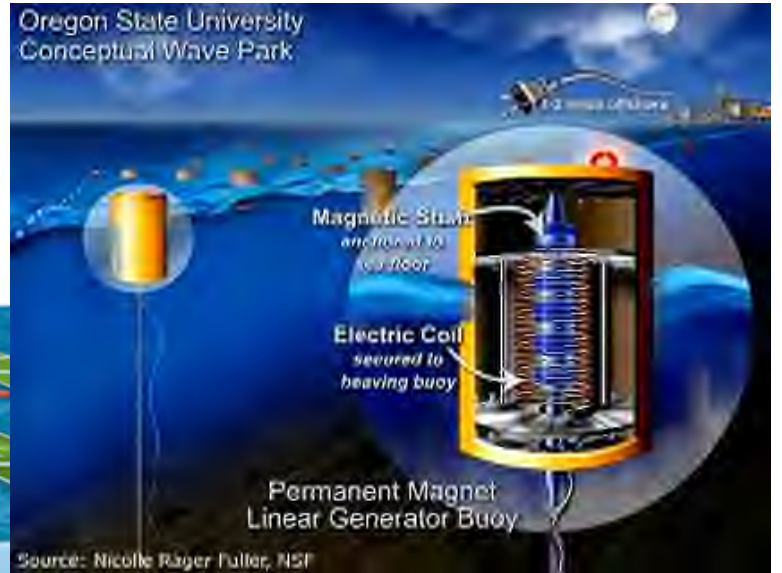
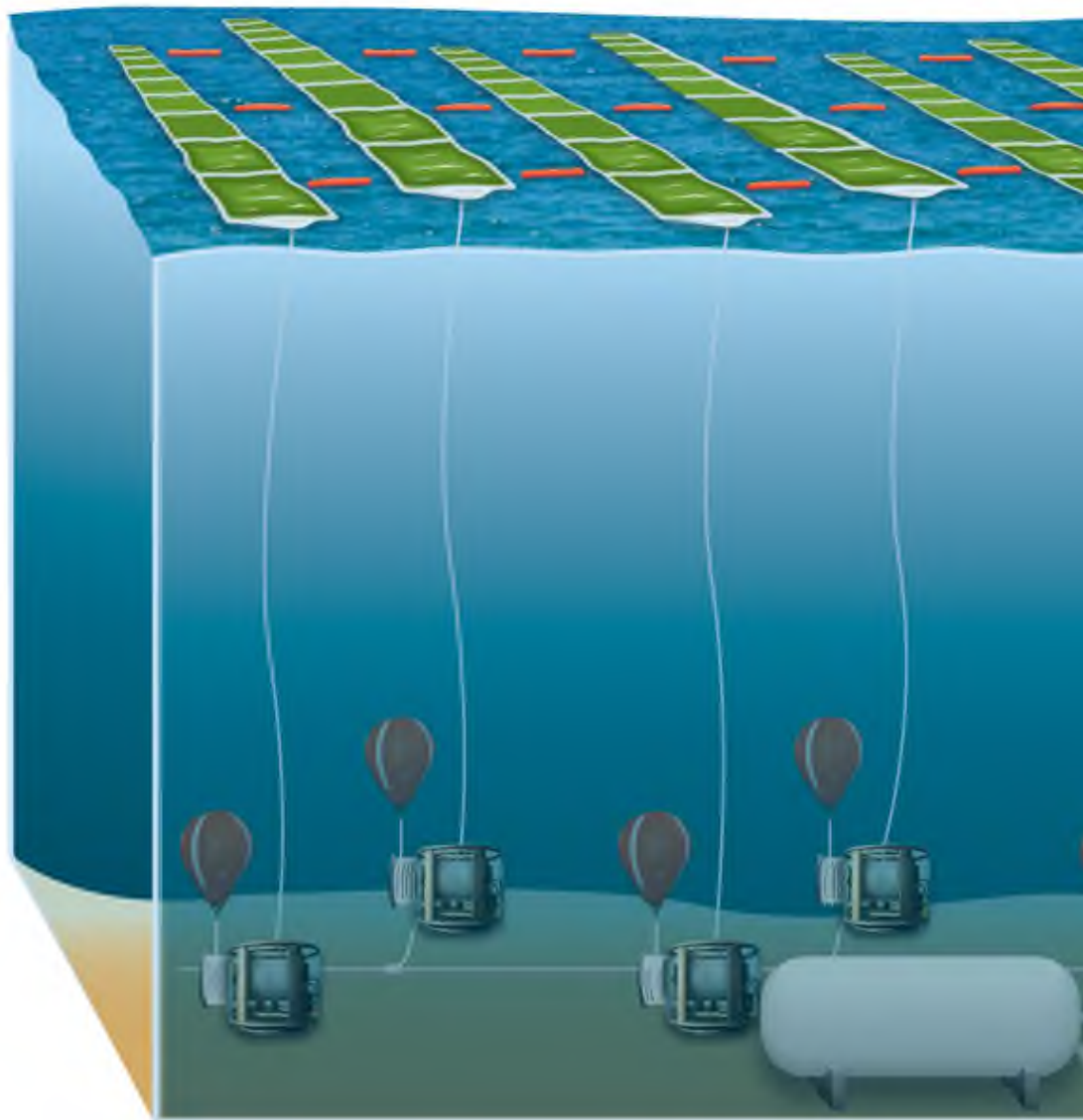
OMEGA logistics?

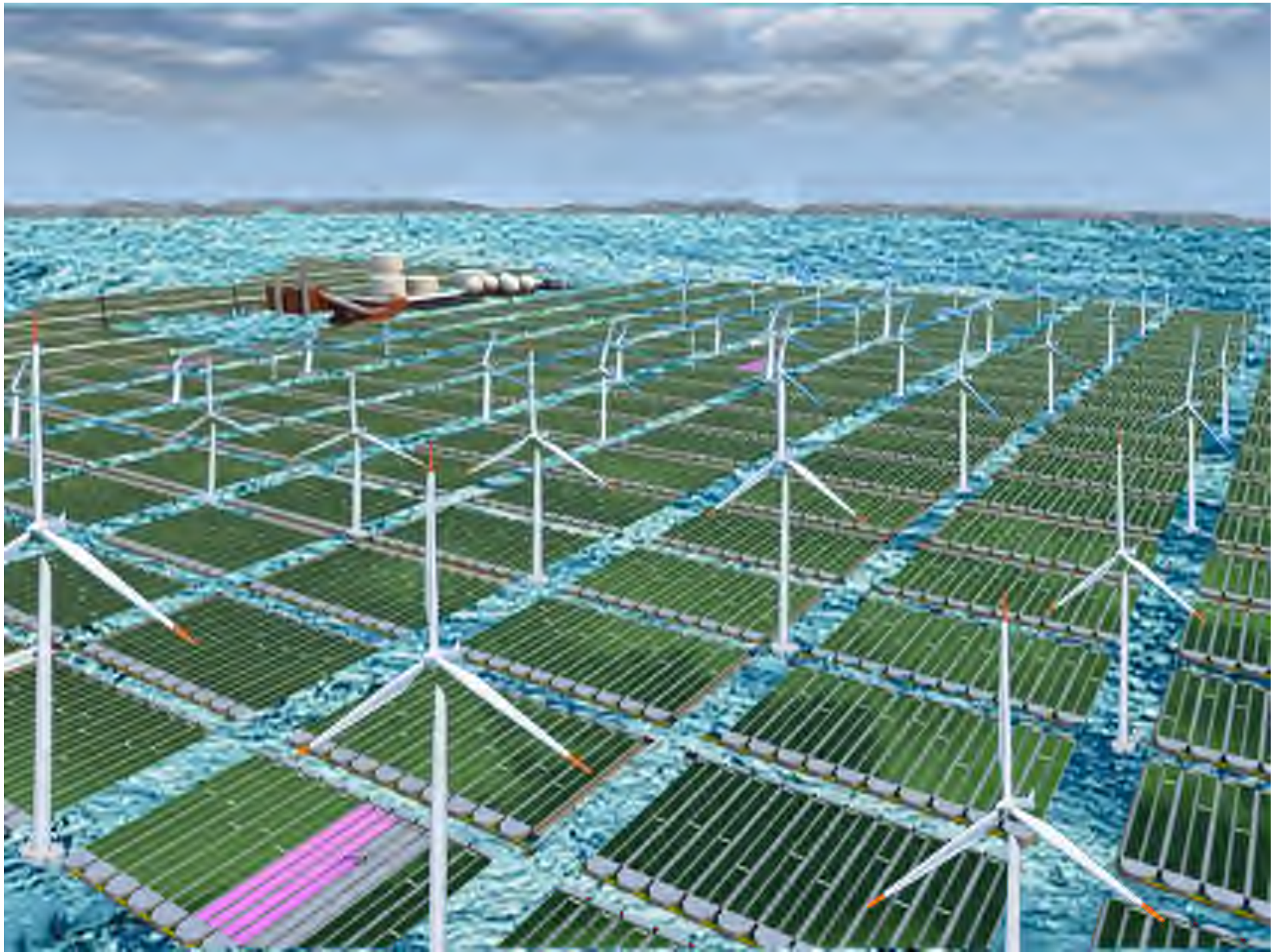






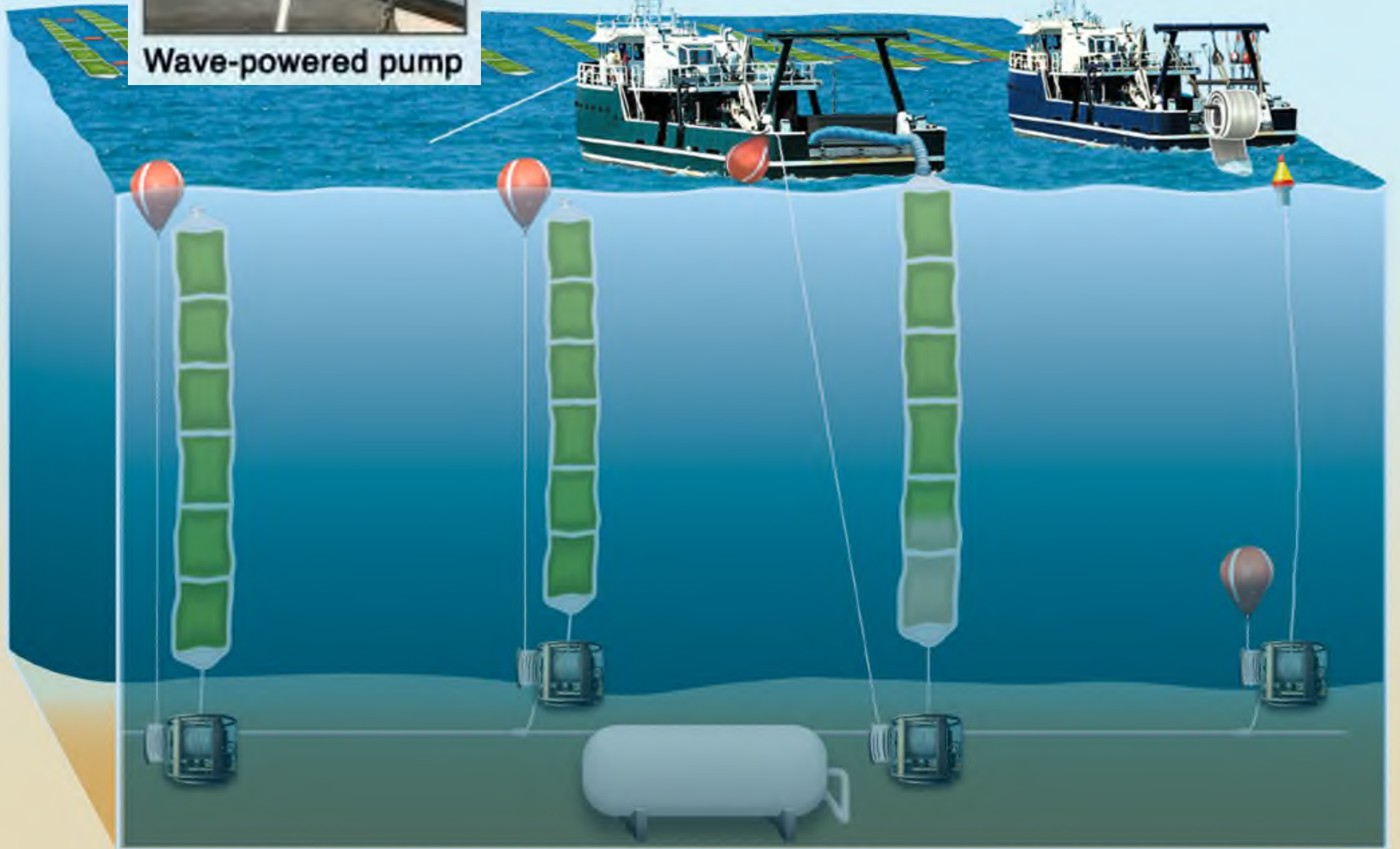






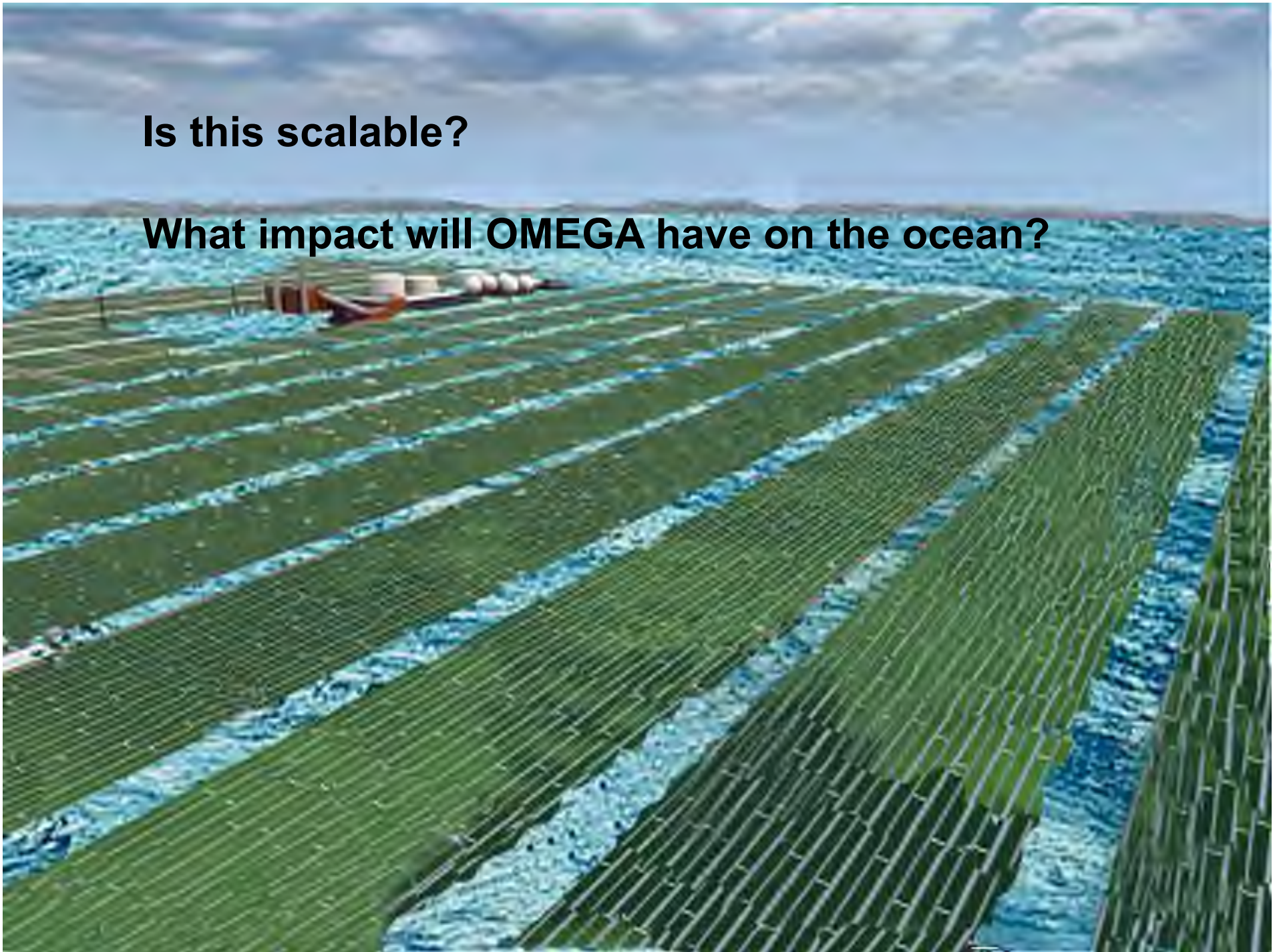


Wave-powered pump



Is this scalable?

What impact will OMEGA have on the ocean?











Jan Parker 2006



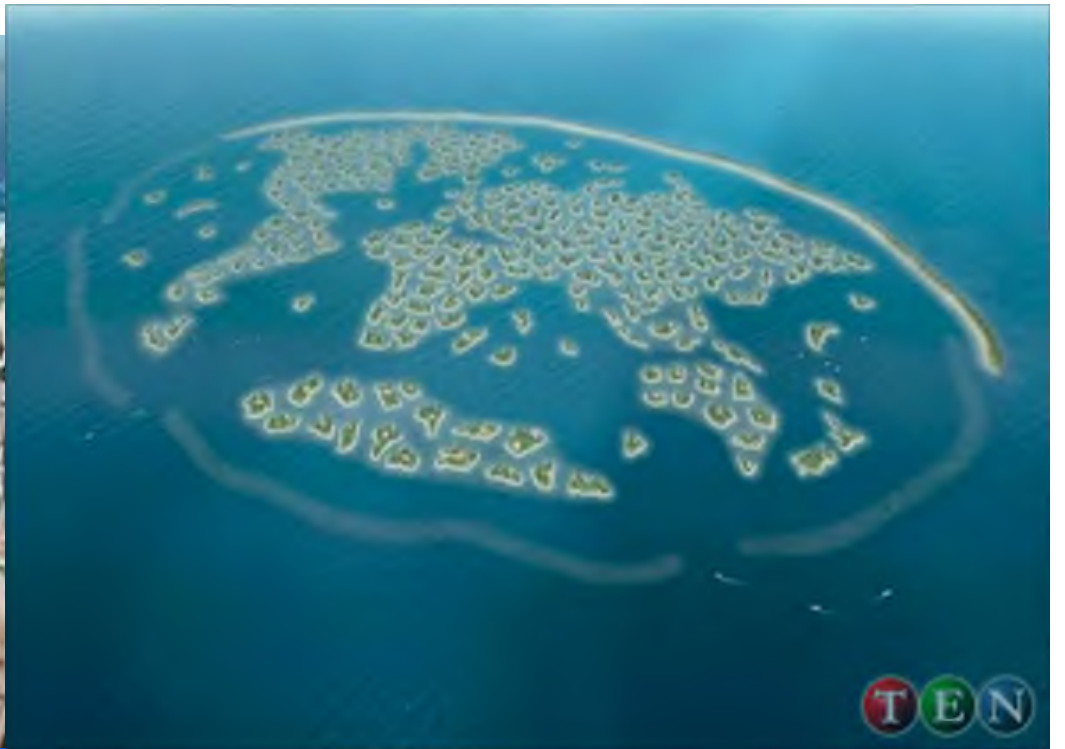
How realistic is OMEGA?



An aerial photograph of a mountain range. The mountains are covered in dense green forest. A road or path winds through a valley between the mountains. The sky is overcast with grey clouds. The overall scene is rugged and scenic.

Are we up to the engineering challenge?



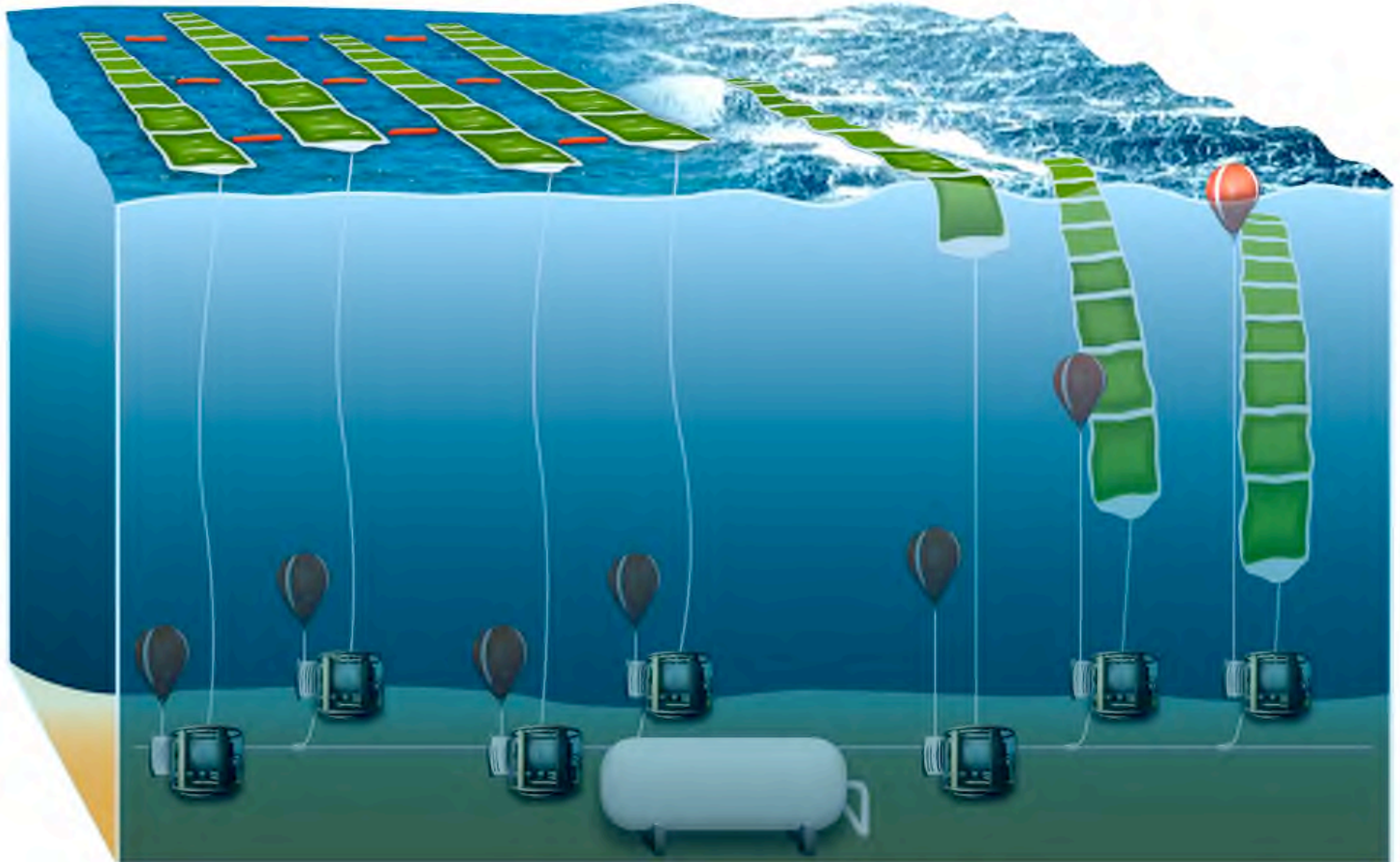
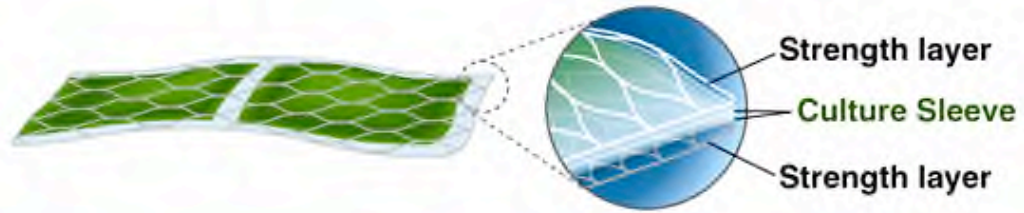


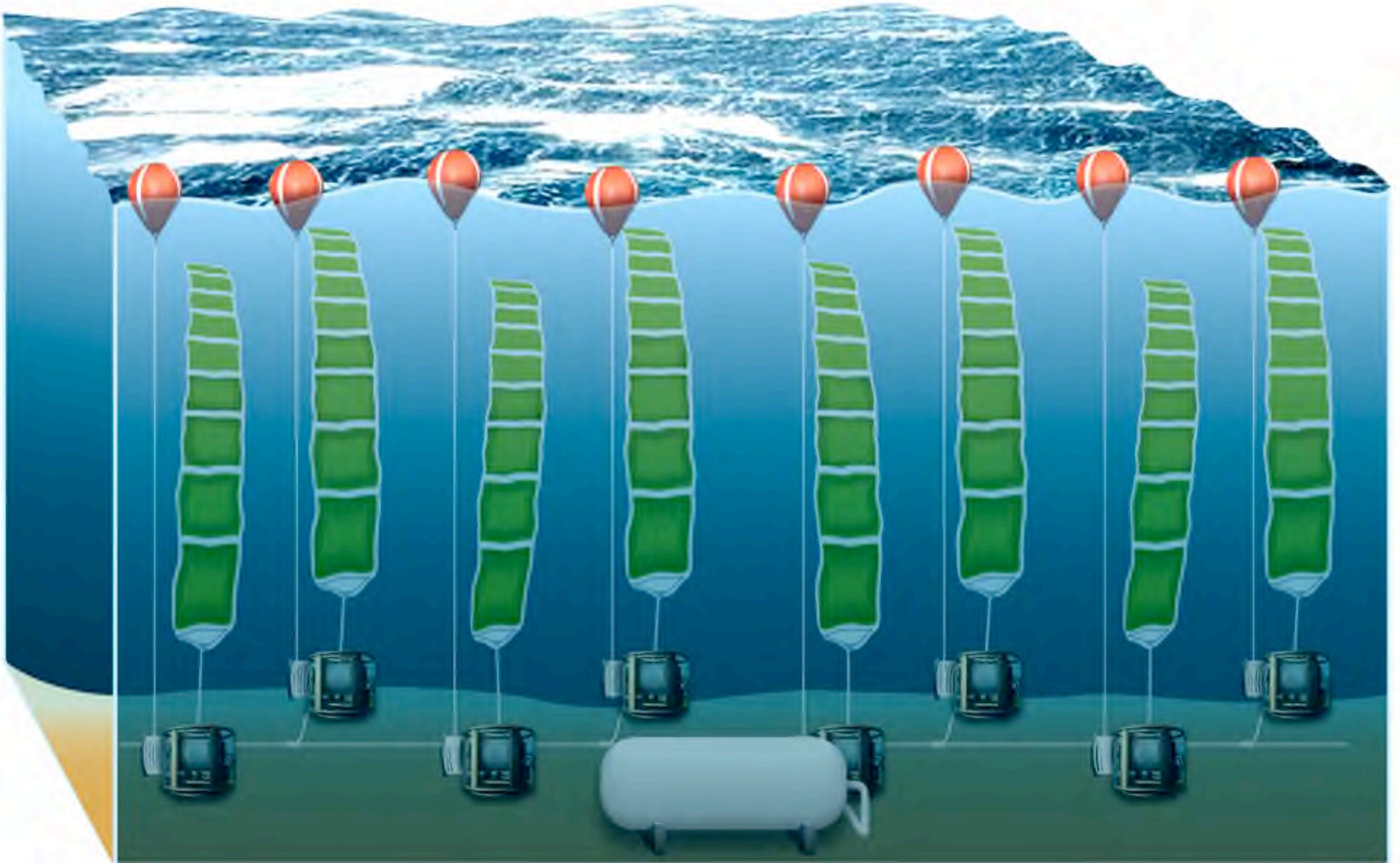
TEN



TEN REAL ESTATE







An aerial photograph of a mountain range with a road winding through the valleys. The mountains are covered in green vegetation, and the sky is overcast with grey clouds. The overall scene is somewhat hazy and atmospheric.

Challenges for OMEGA

- !**Biology**
- !**Engineering**
- !**Economics**
- !**Environment**

NASA OMEGA

Demonstration Project



Motivations for OMEGA

Does not compete with agriculture

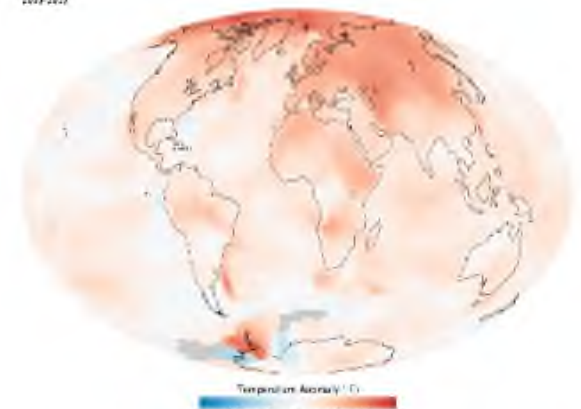
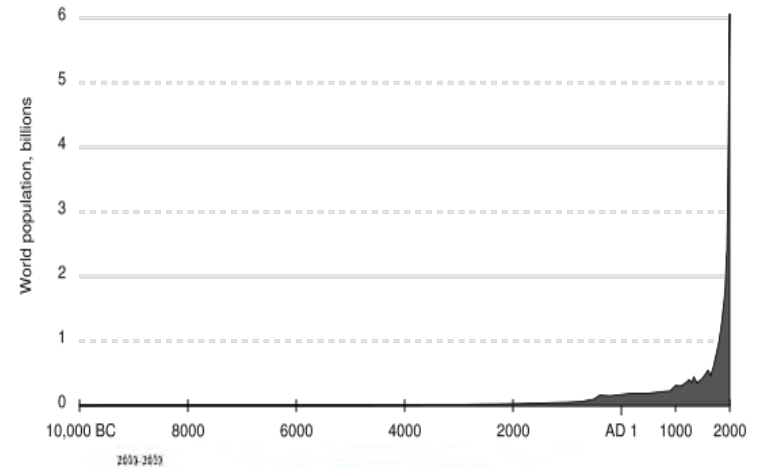
- !Land
- !Freshwater
- !Fertilizer

Compatible with climate change

- Not dependent on rain
- Flooded coastal zones
- Warming ocean surface

Creates an ecology of technology

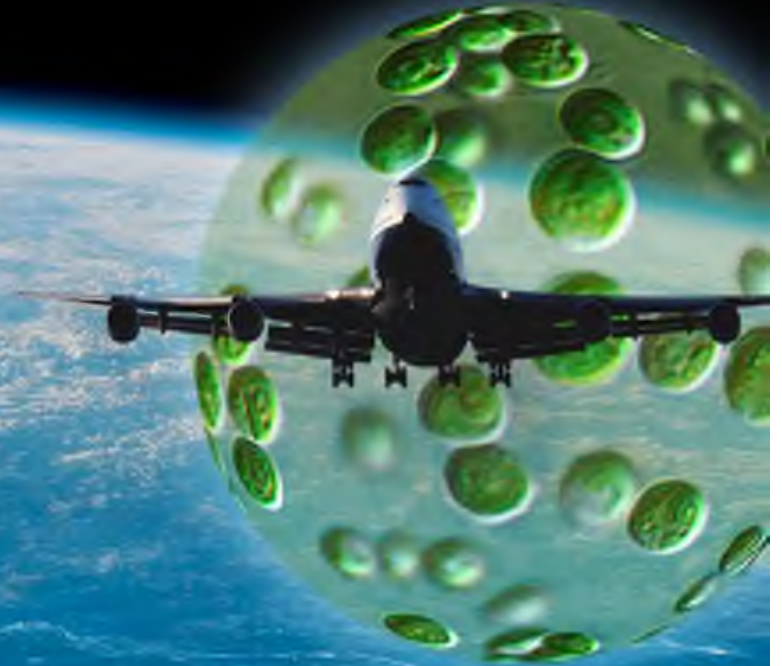
- !Waste = resource

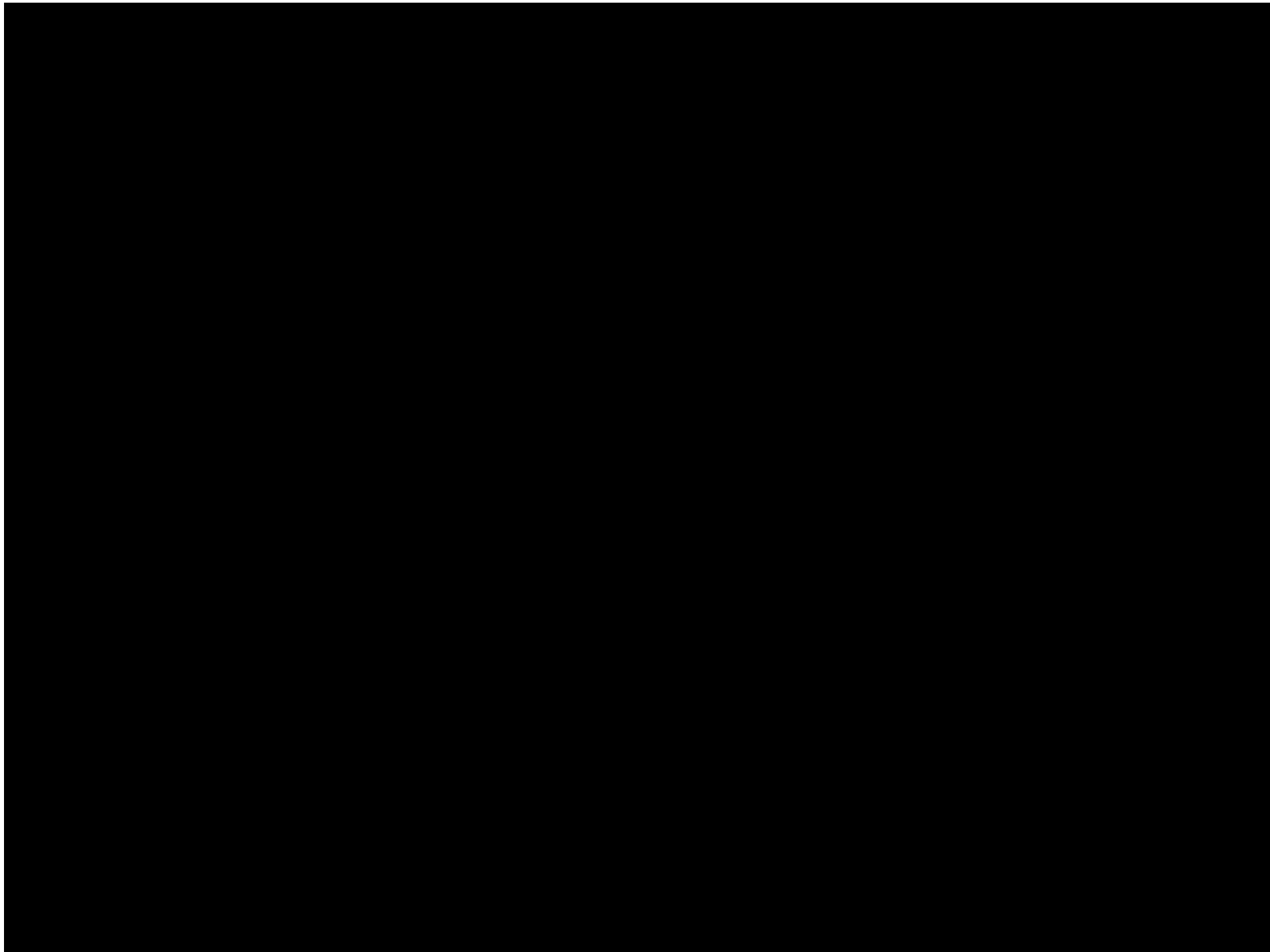




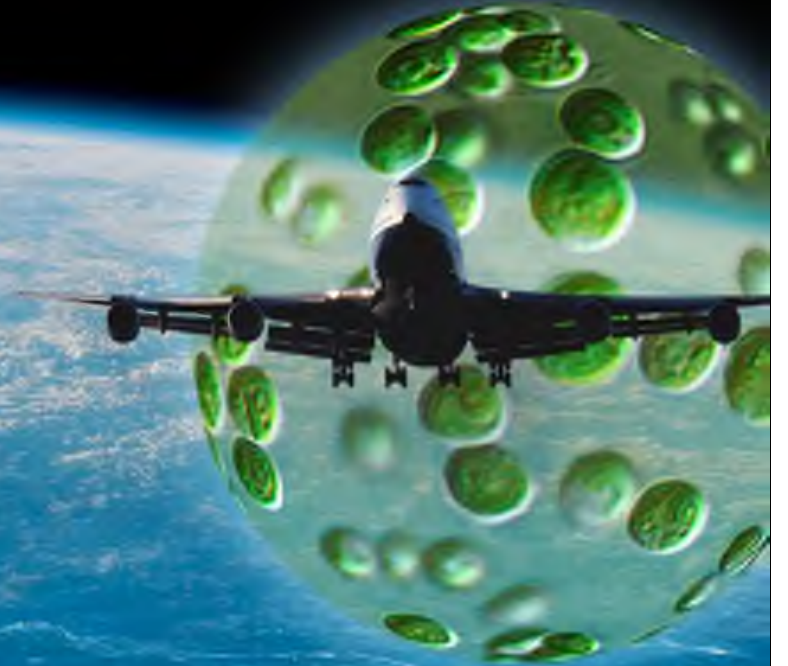
“...what we really want is for things to stay the same, but get better.”

Is the future really in algae?



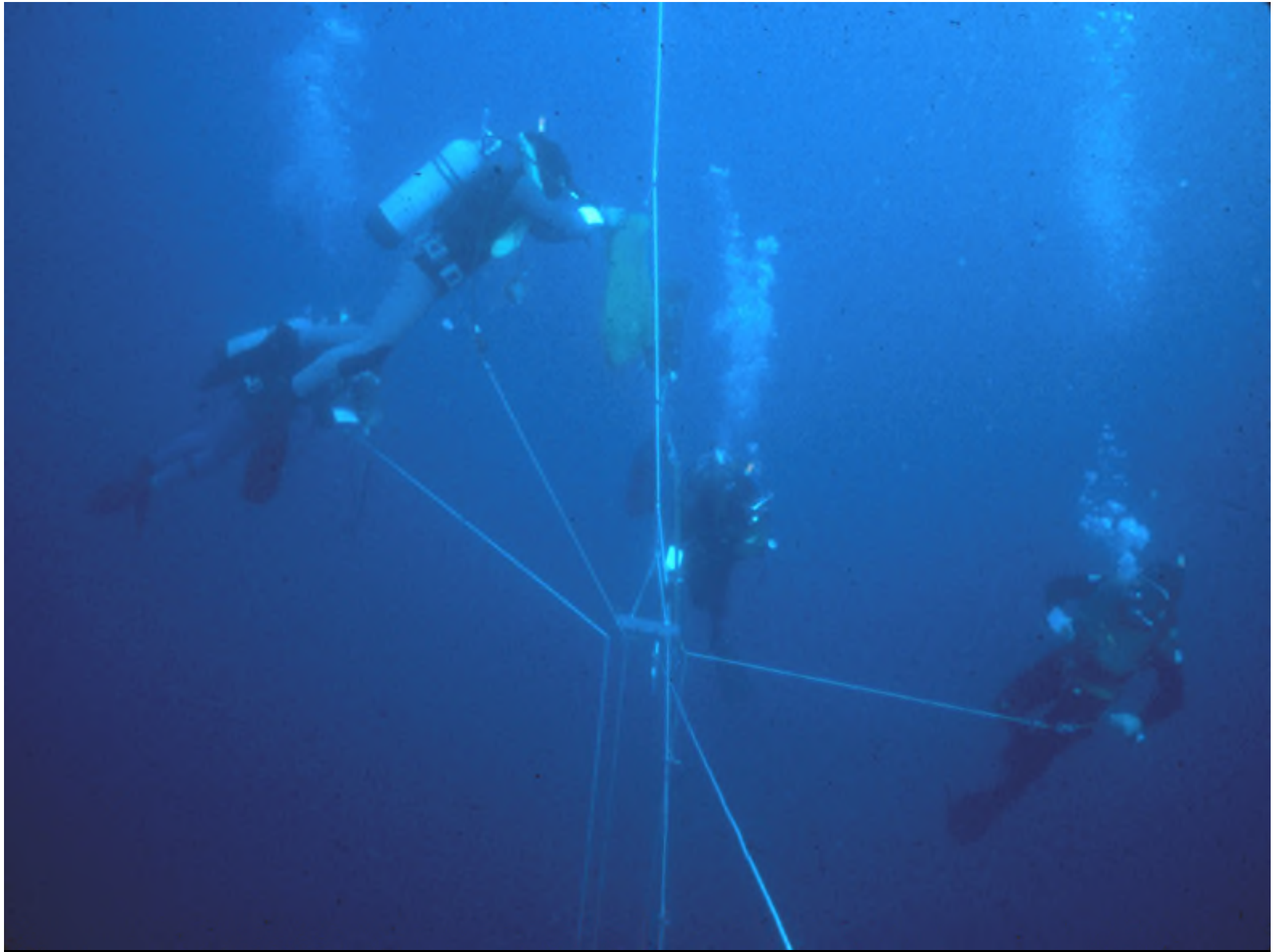


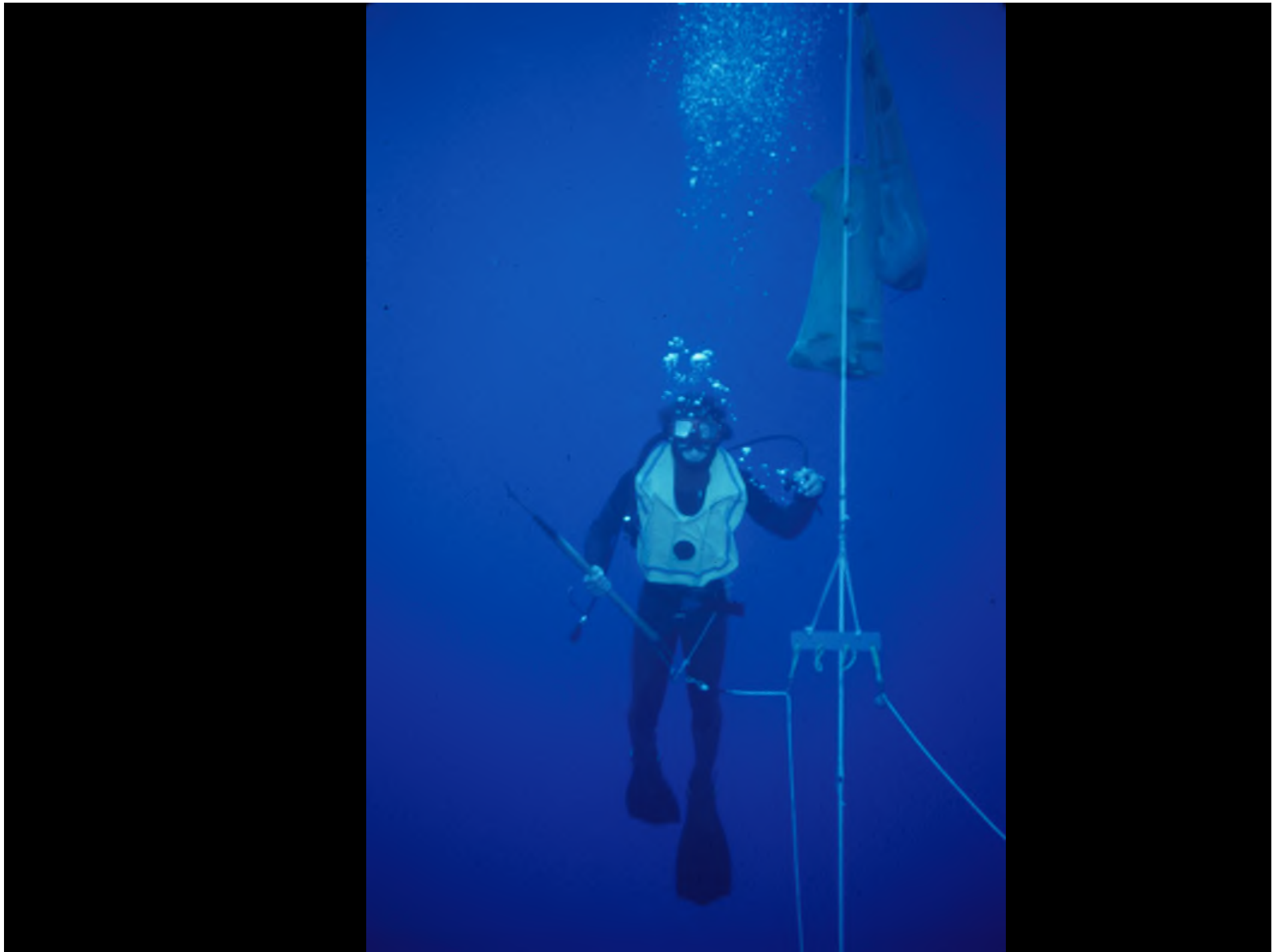
***What about collecting wild
algae from the ocean?***

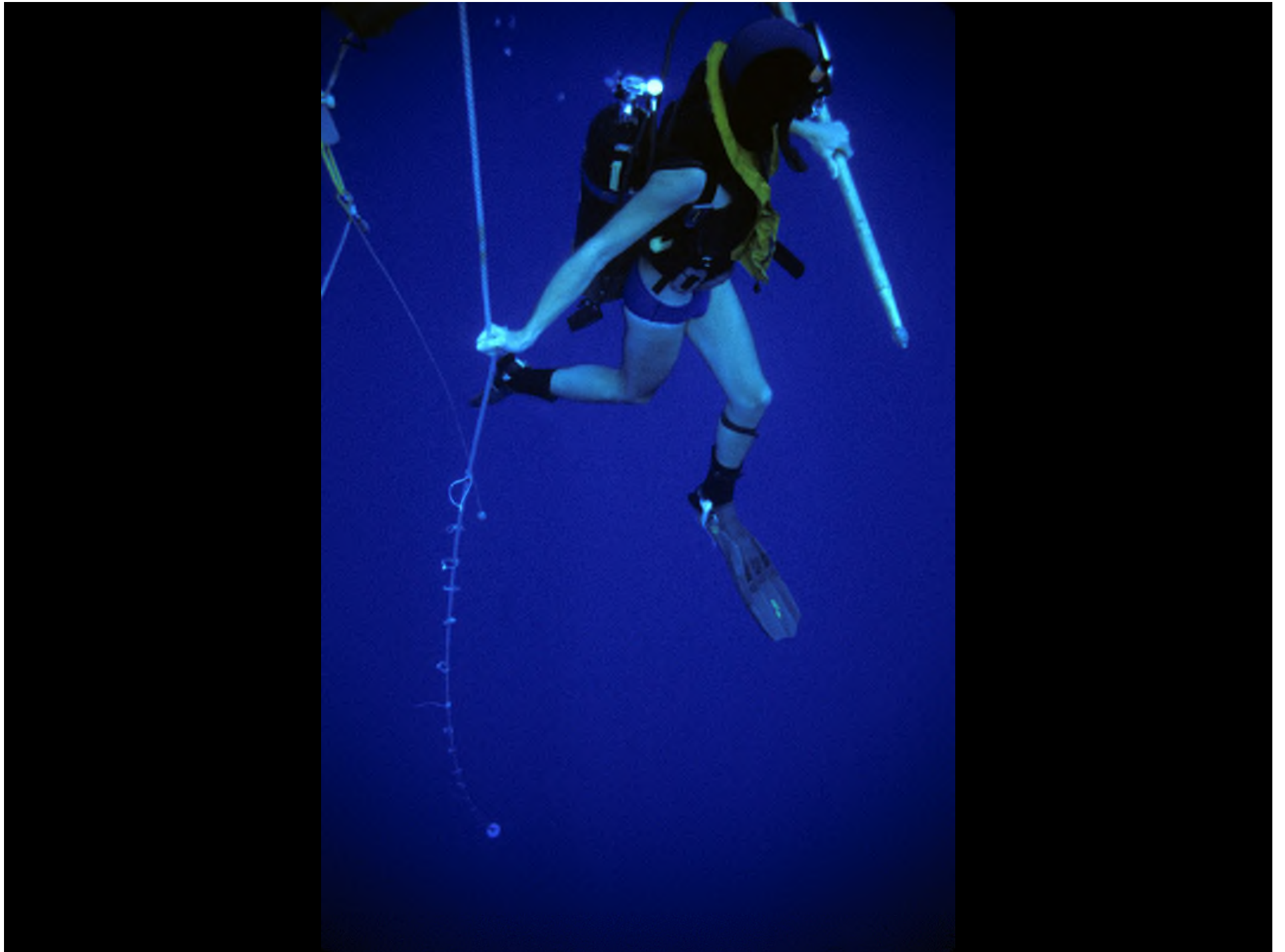






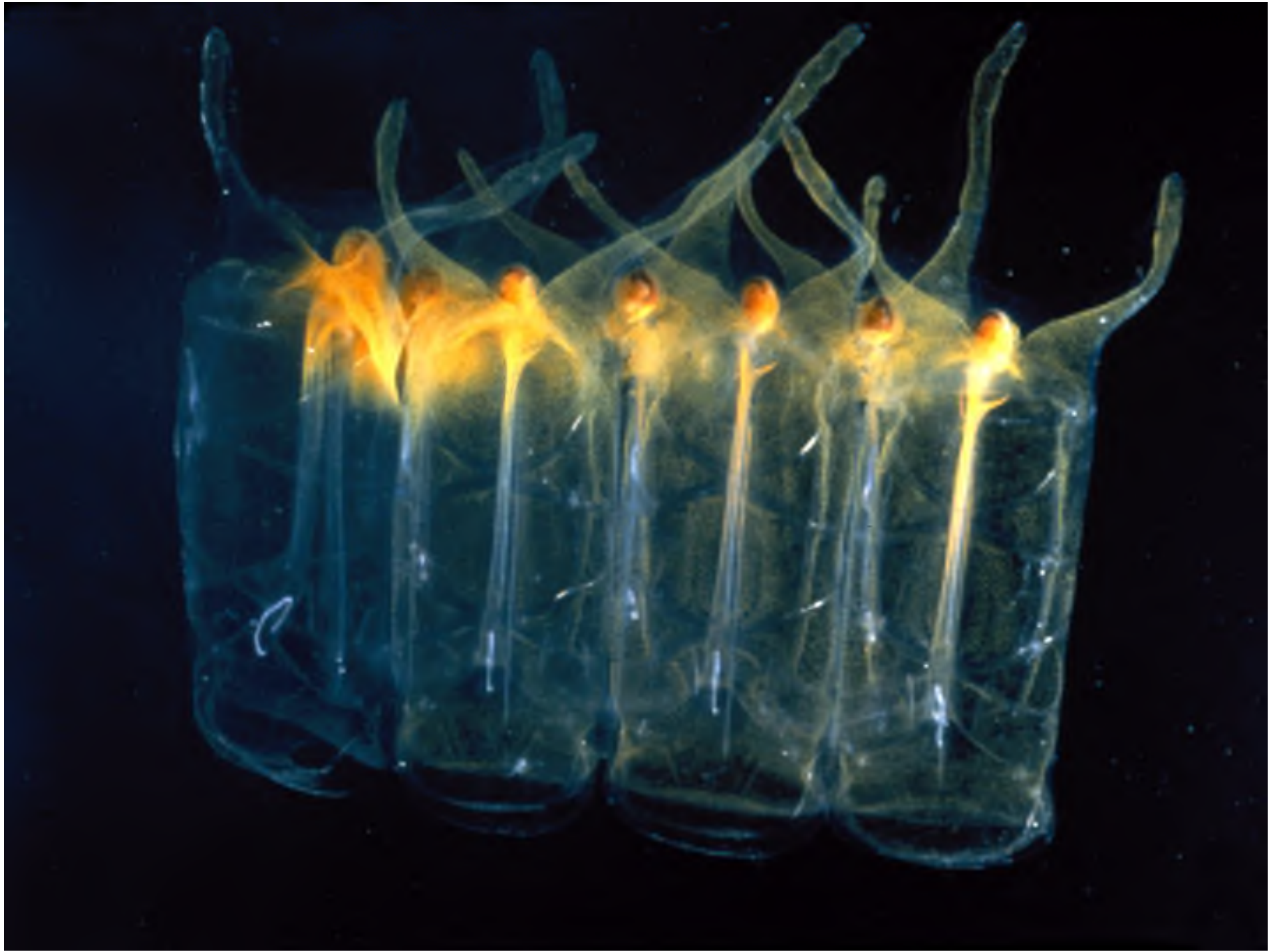














**Harvest
wild algae?**

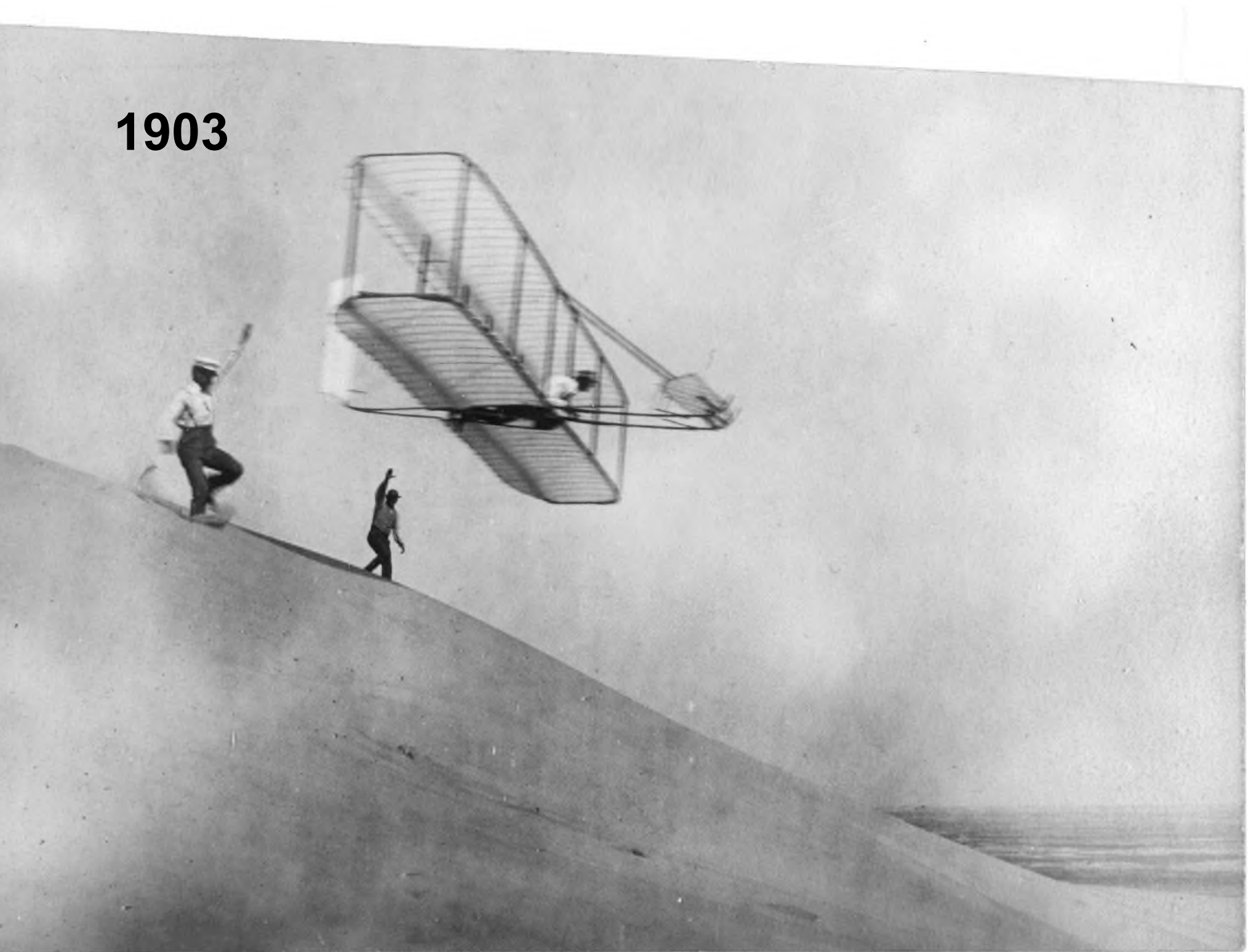
Concentration?

Spatially/temporally dispersed?

Species composition?



1903



July 20, 1969







**The stone age didn't end
because we ran out of stones... Yamani**

**There is no limit to what you can accomplish
If you don't care who gets the credit... Truman**

