Is the future really in algae?

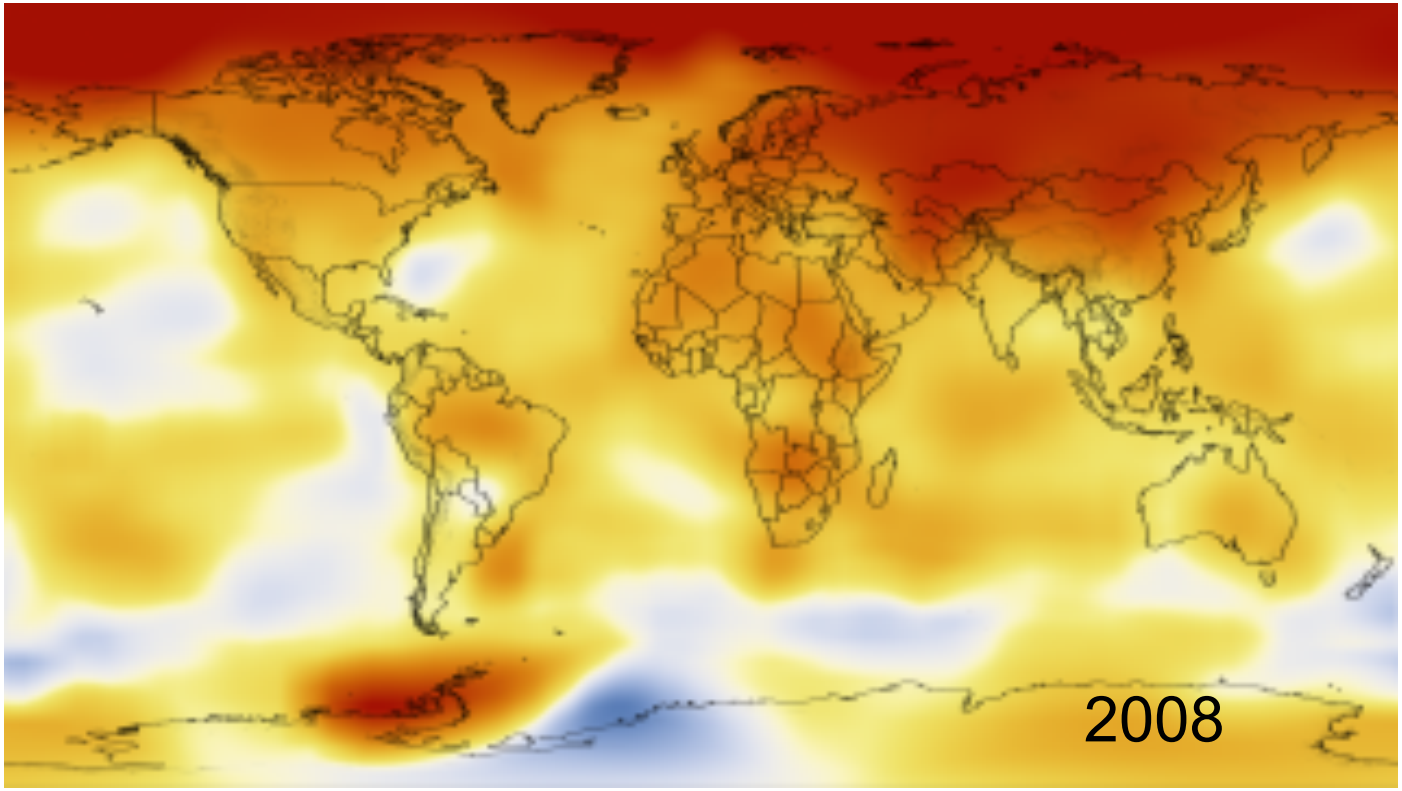
OMEGA for the future of biofuels

OMEGA for the future

OMEGA

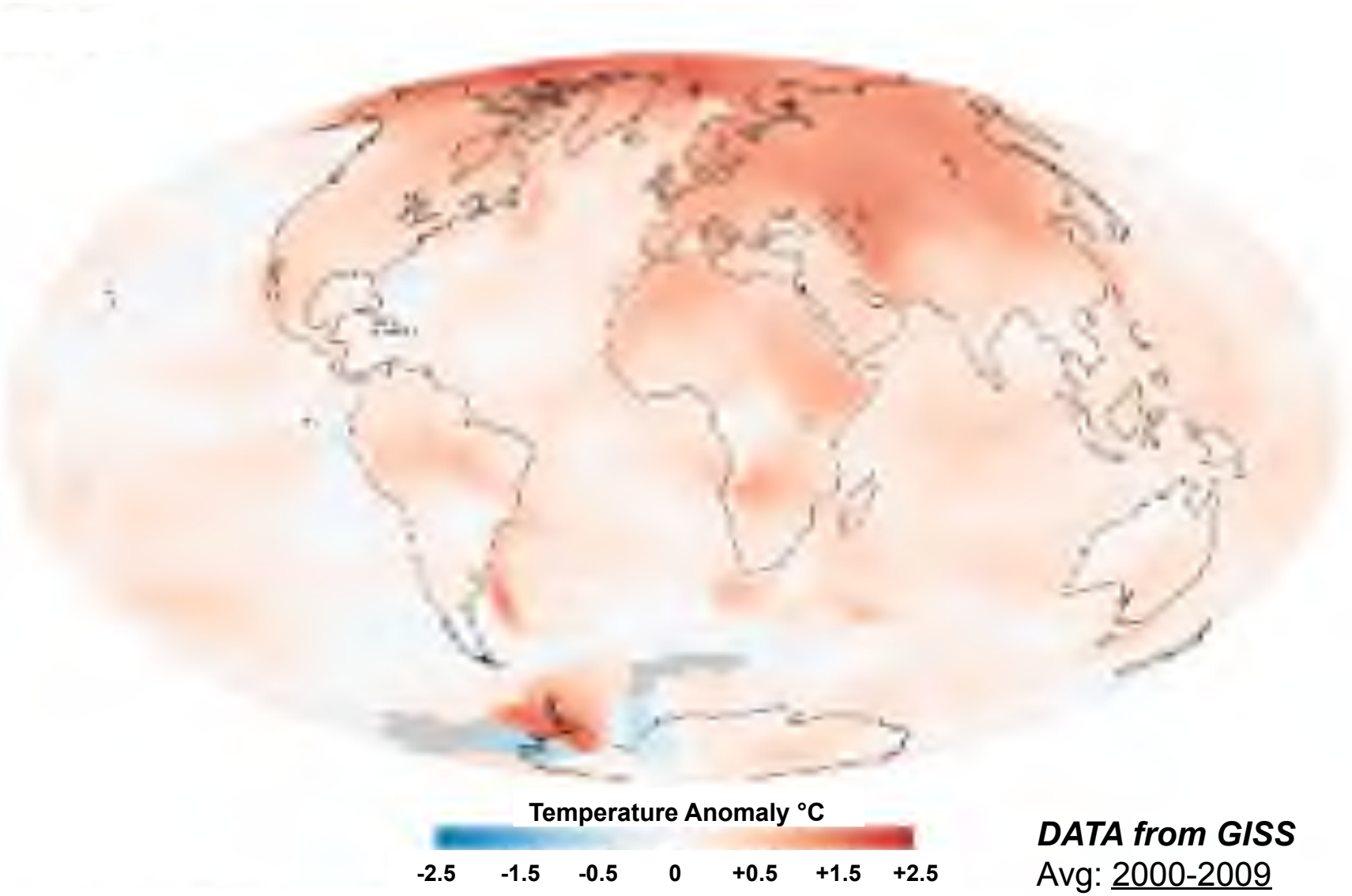
Jonathan Trent, Ph.D.
NASA Ames Research Center
Jonathan.d.trent@nasa.gov

MB Marine Sanctuary
10 April 2010



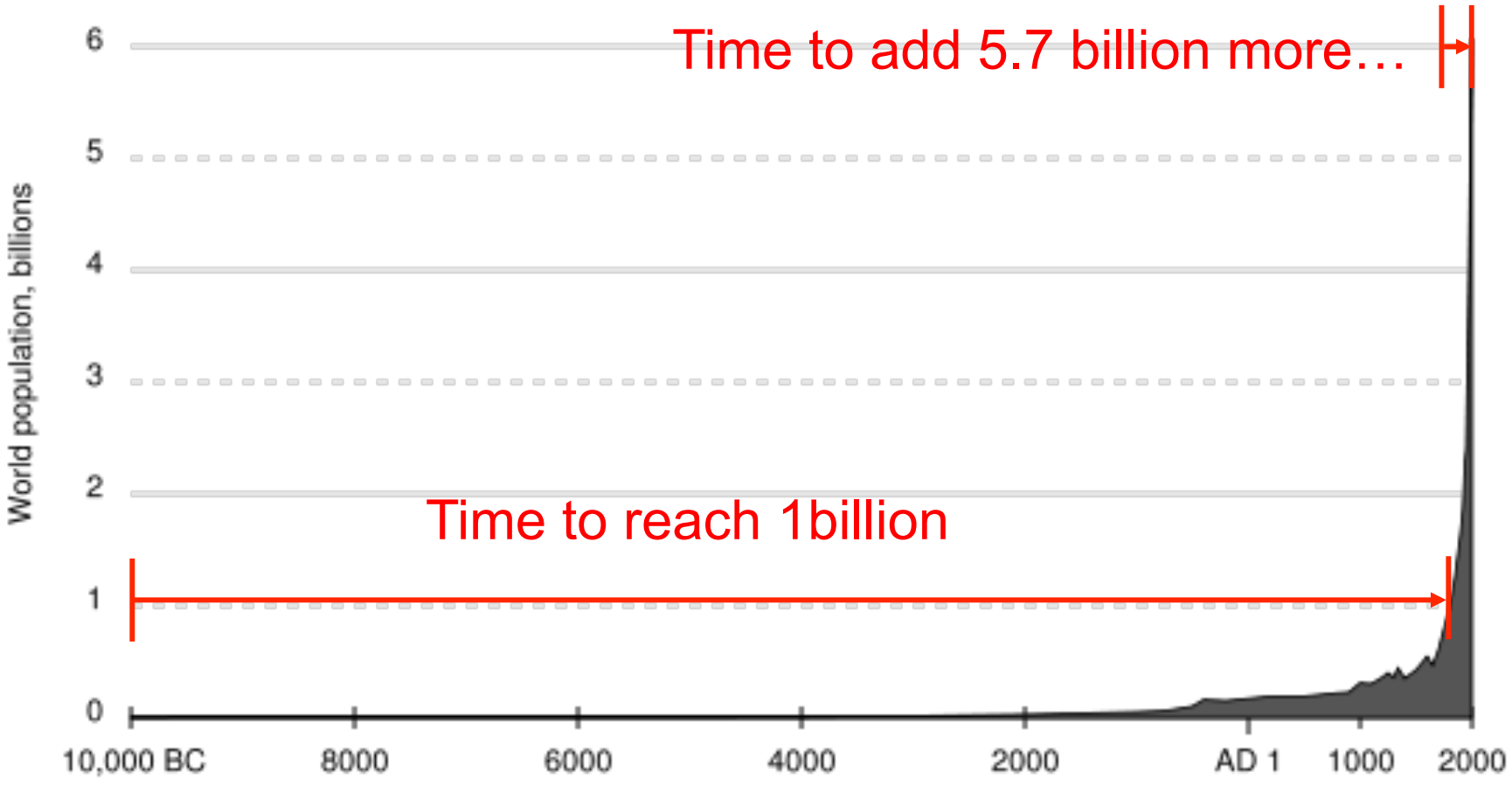
Data from NASA/Goddard Space Flight Center
James Hansen, Goddard Institute of Space Studies
Robert B. Schmunk, Scientific Visualization Studio

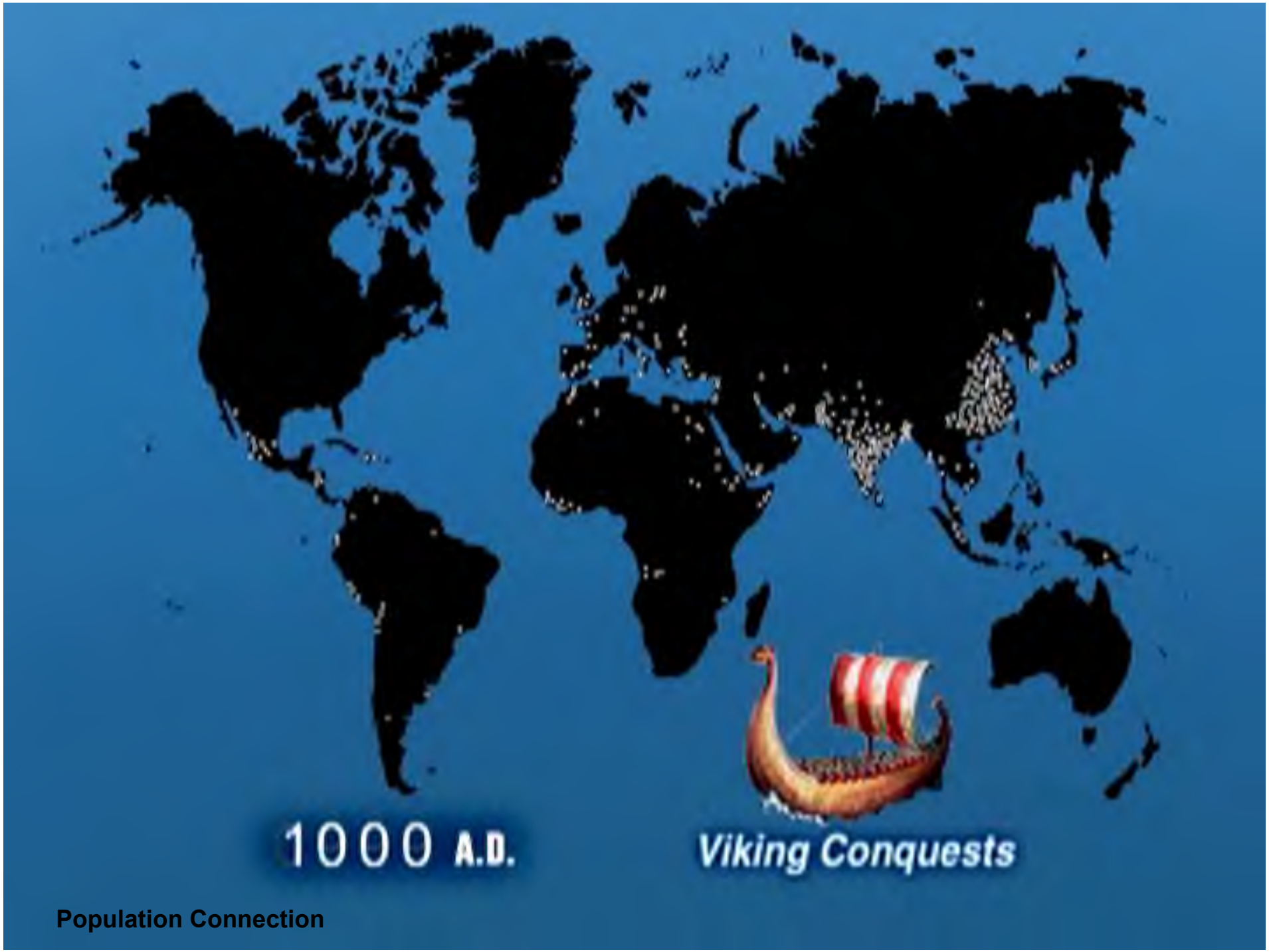
The warmest decade on record…



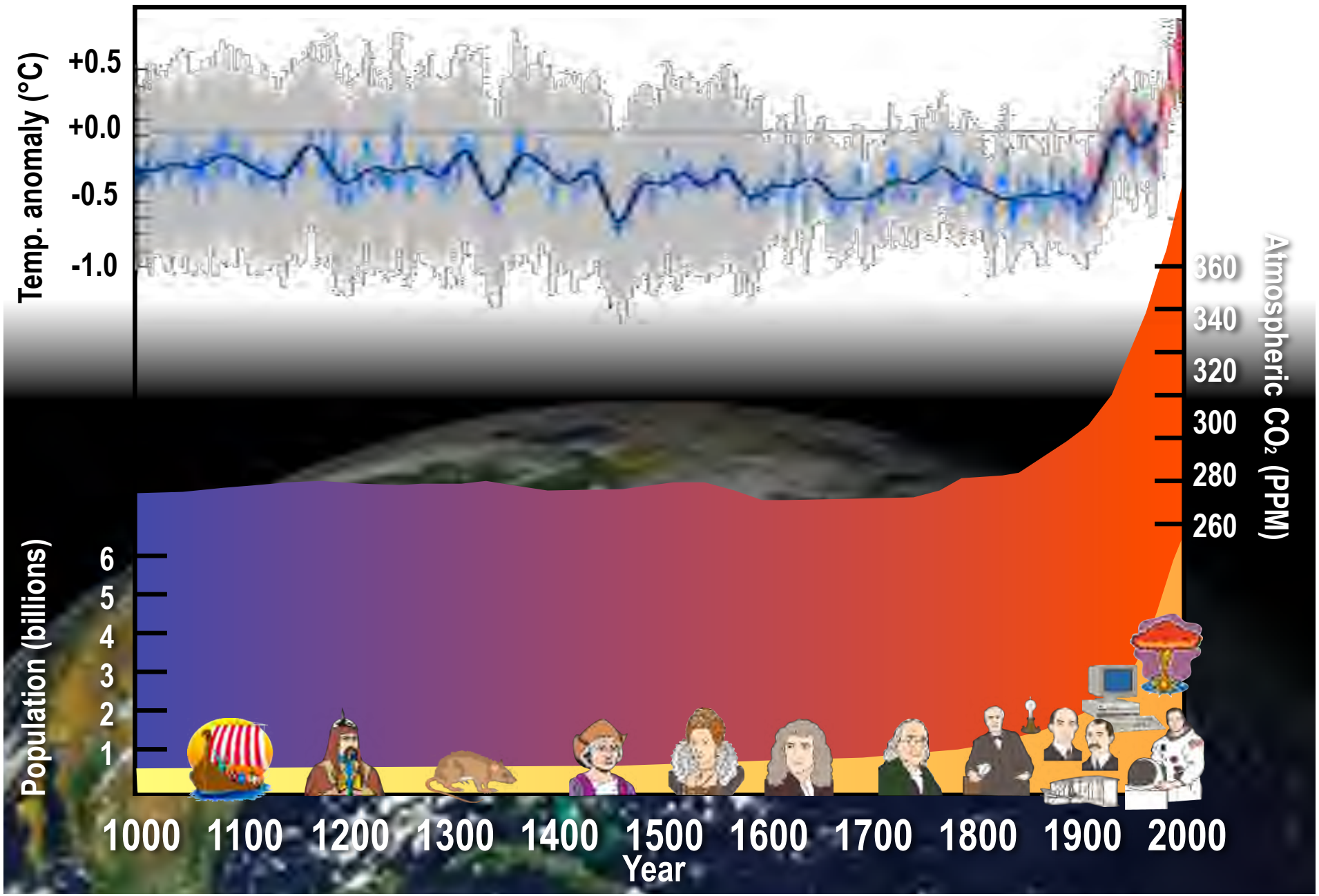
DATA from GISS
Avg: 2000-2009
1951-1980

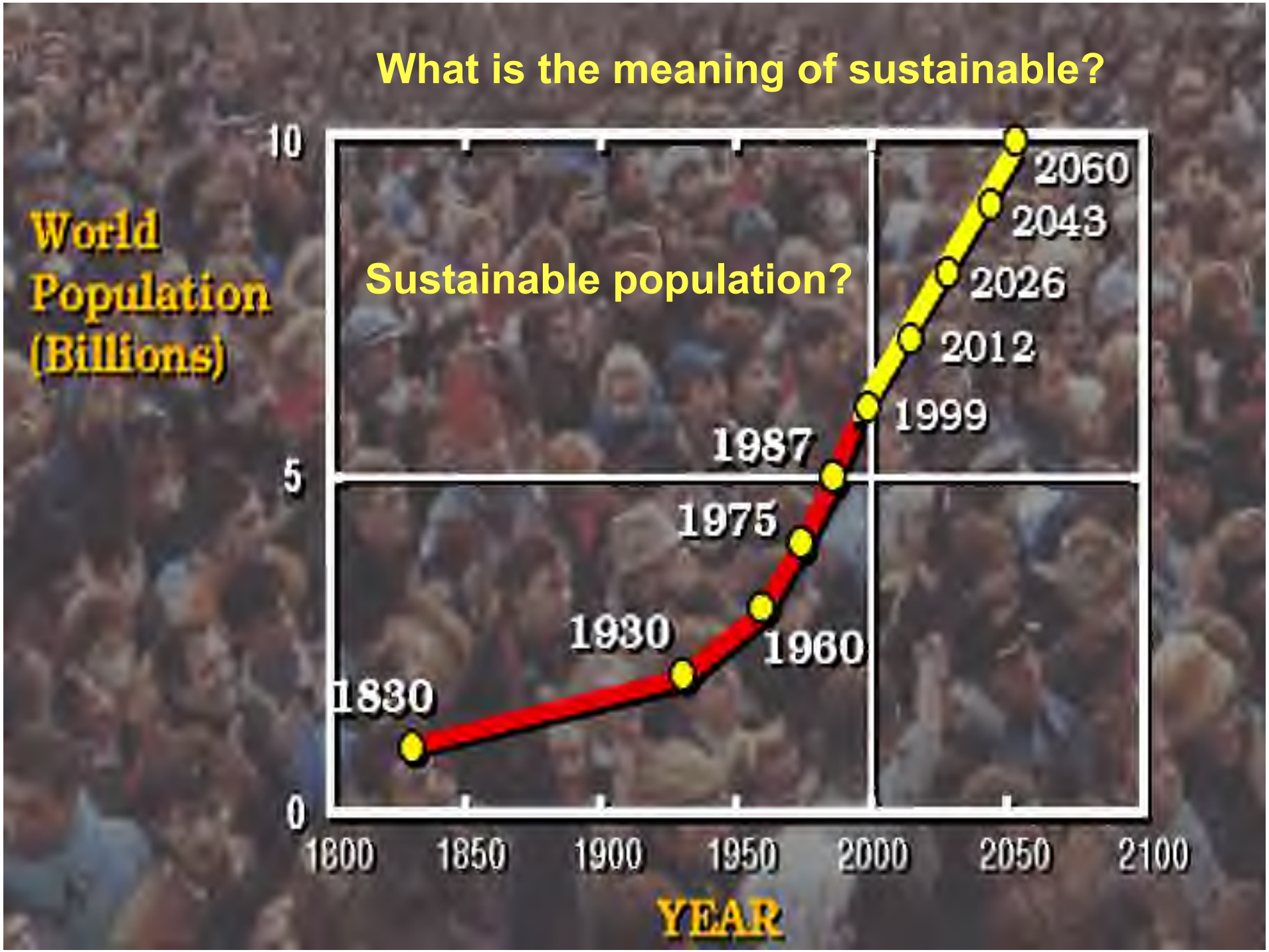
Limits to growth?

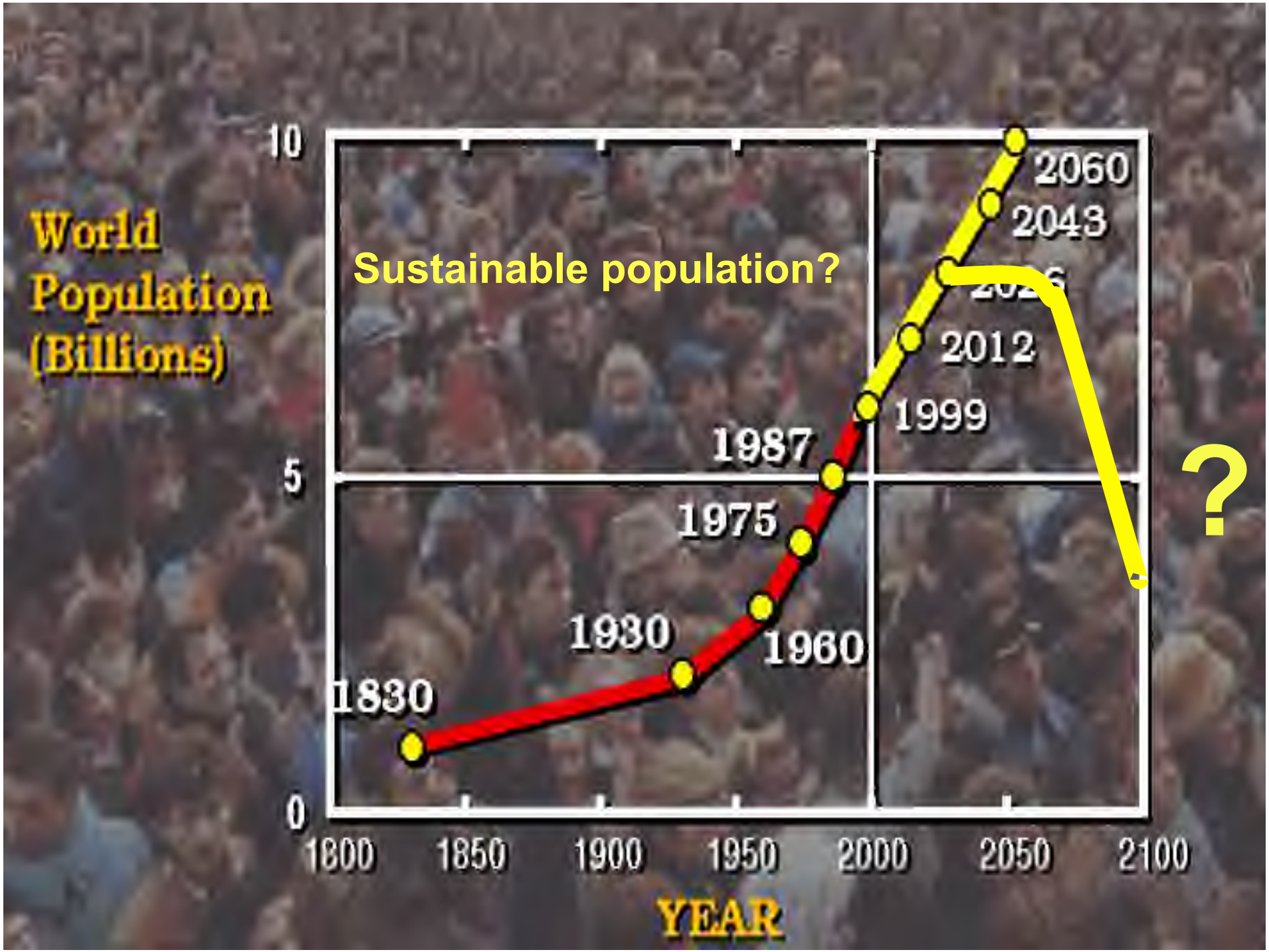


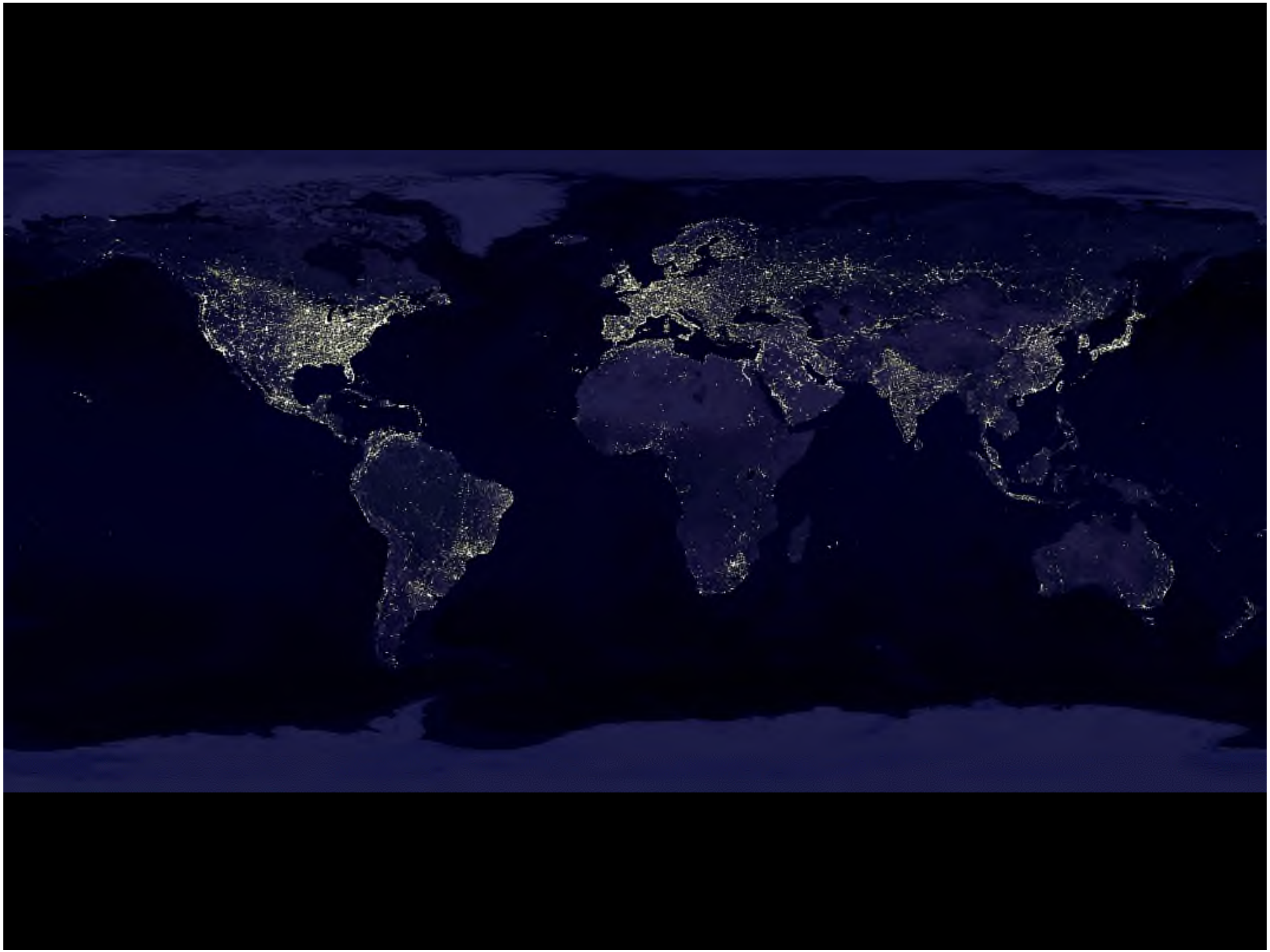


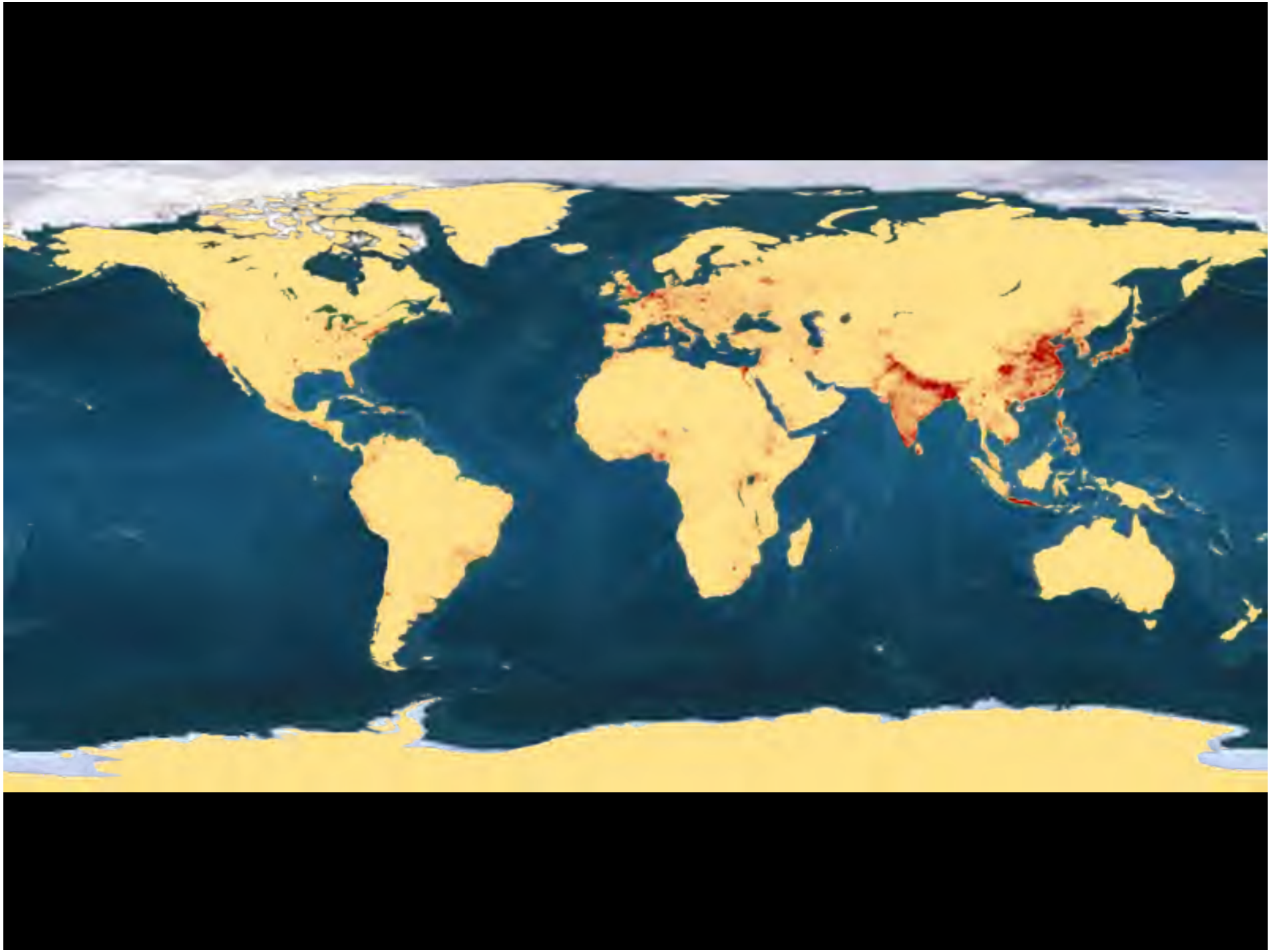
Population Connection

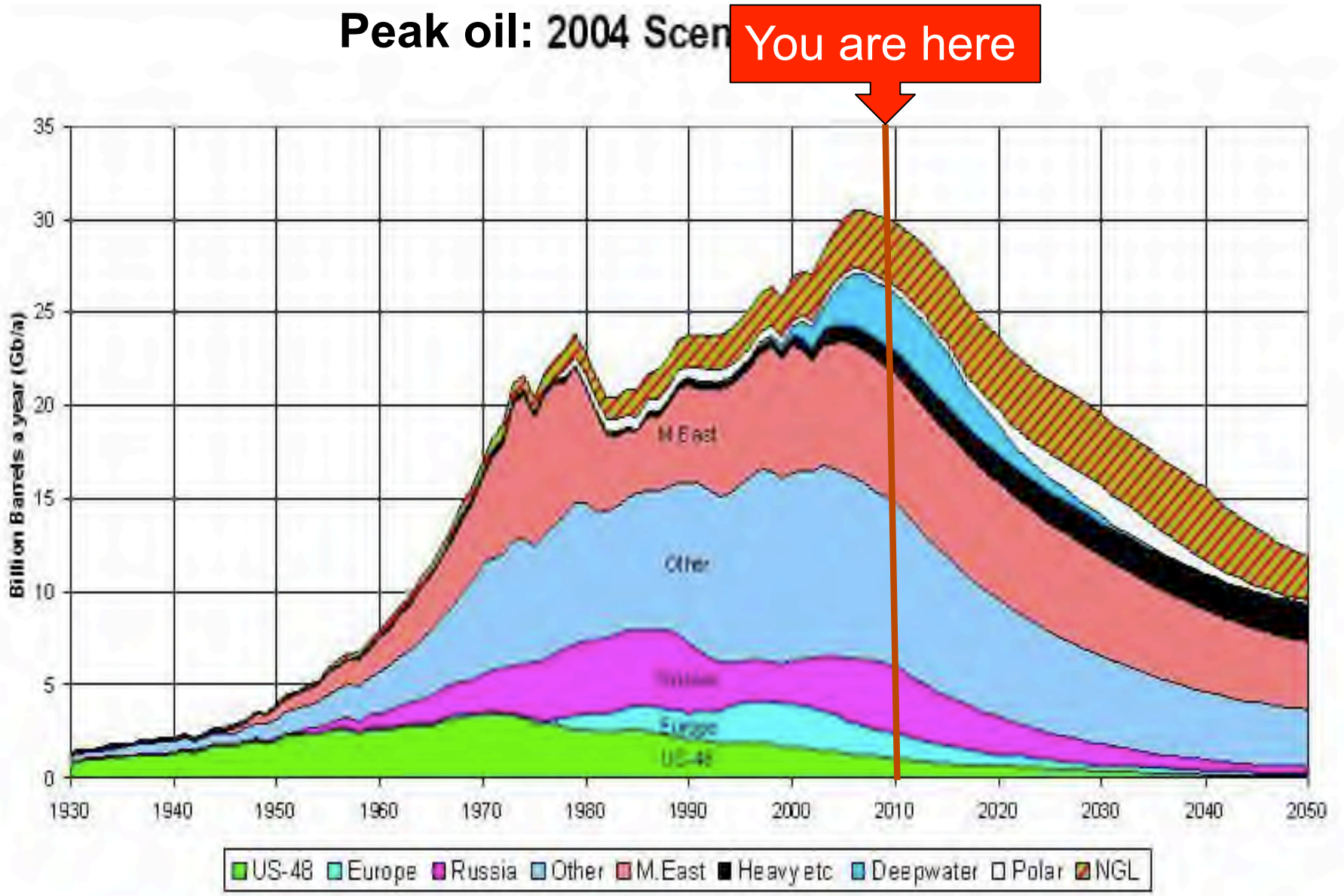

Temp. anomaly (°C)
+0.5
+0.0
-0.5
-1.0
Atmospheric CO_2 (PPM)
360
340
320
300
280
260
Population (billions)
6
5
4
3
2
1
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Year

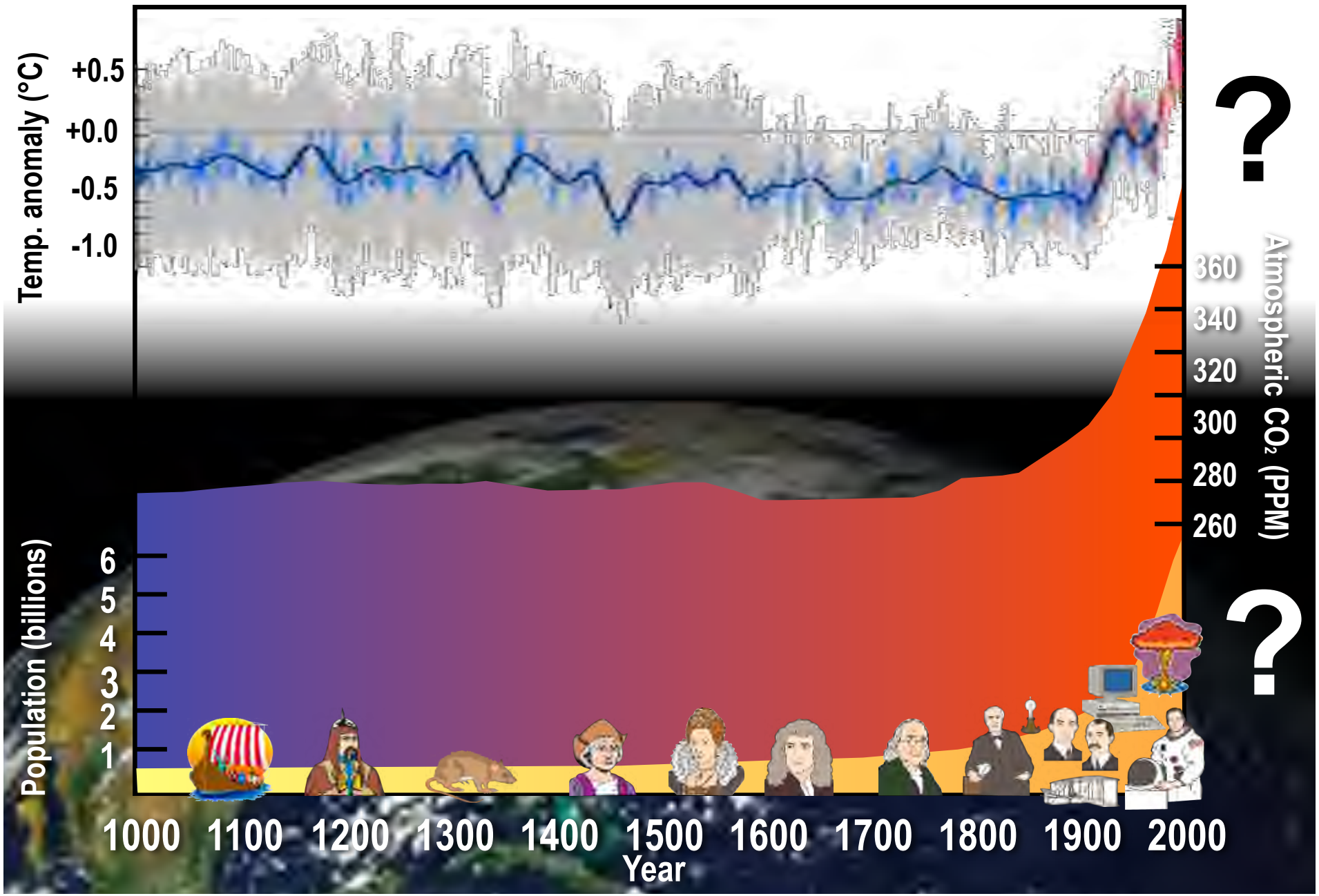

What is the meaning of sustainable?
Sustainable population?
World Population (Billions)
10
5
0
1800
1850
1900
1950
2000
2050
2100
YEAR
1830
1930
1960
1975
1987
1999
2012
2026
2043
2060

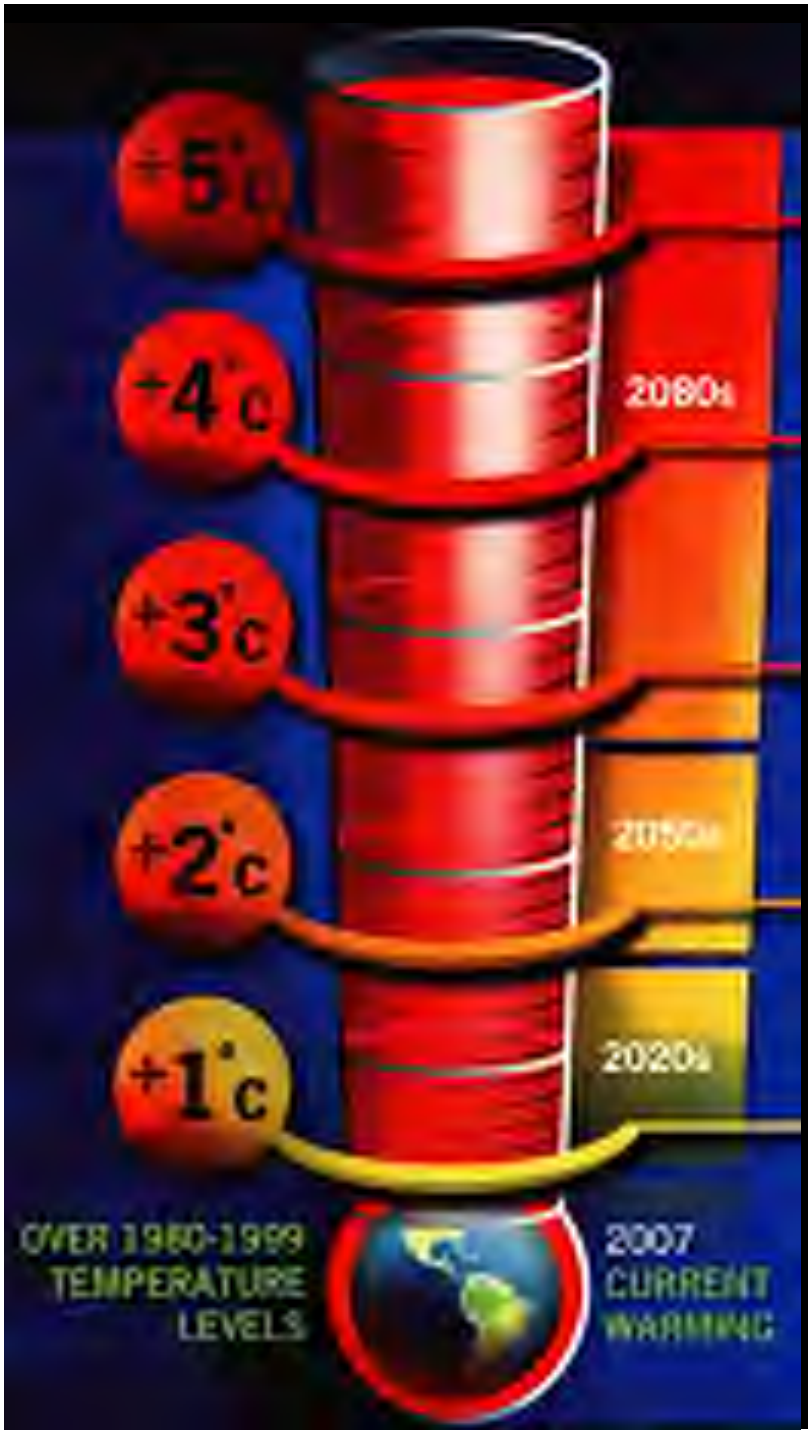

World Population (Billions)
10
5
0
Sustainable population?
2060
2043
2012
1999
1987
1975
1960
1930
1830
?
1800
1850
1900
1950
2000
2050
2100
YEAR






Peak oil: 2004 Scen
You are here
Billion Barrels a year (Gb/a)
35
30
25
20
15
10
5
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
M East
Other
US-48
US-48
Europe
Russia
Other
M.East
Heavy etc
Deepwater
Polar
NGL


Temp. anomaly (°C)
+0.5
+0.0
-0.5
-1.0
?
Atmospheric CO_2 (PPM)
360
340
320
300
280
260
?
Population (billions)
6
5
4
3
2
1
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Year



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

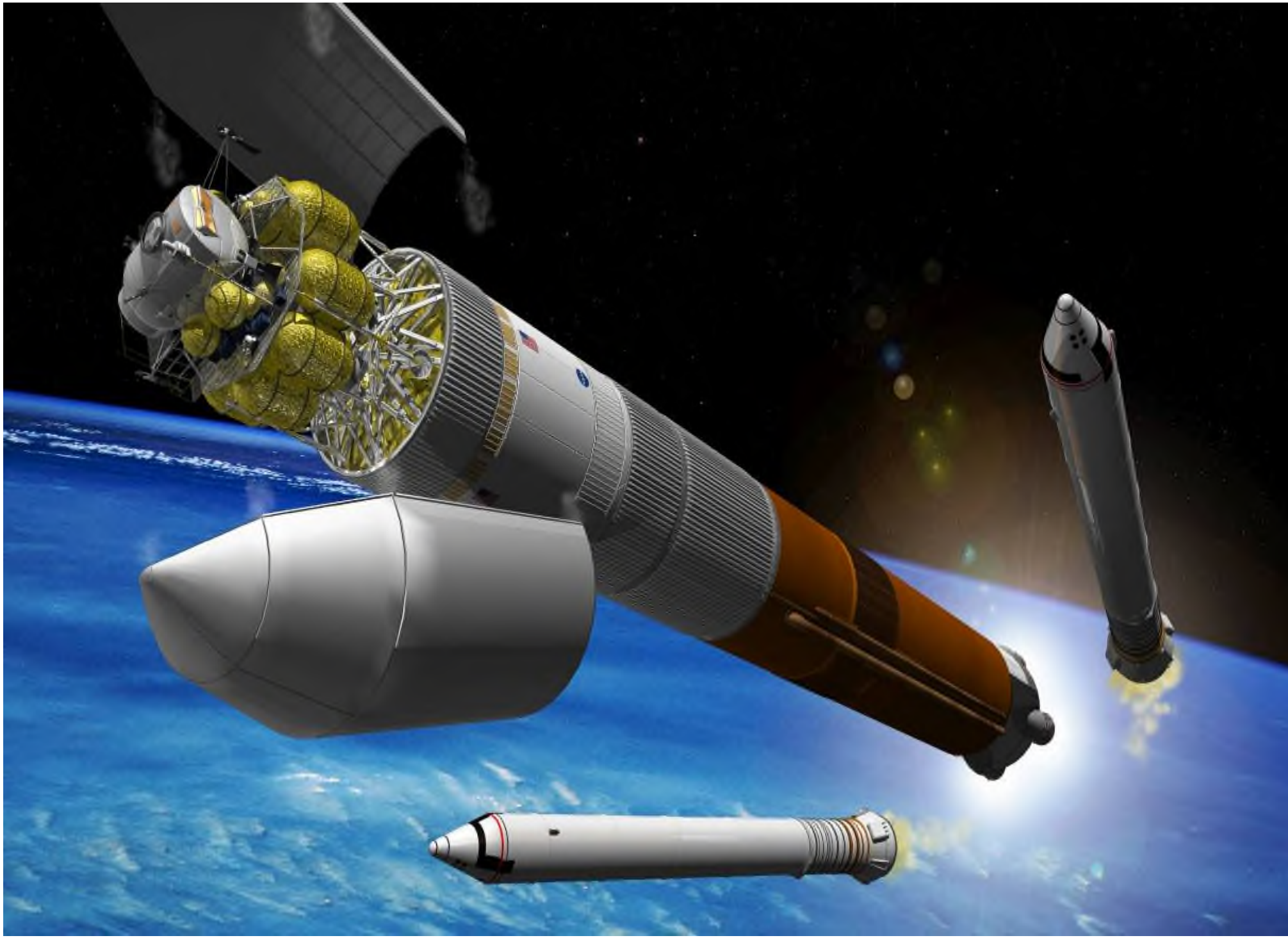
Food?

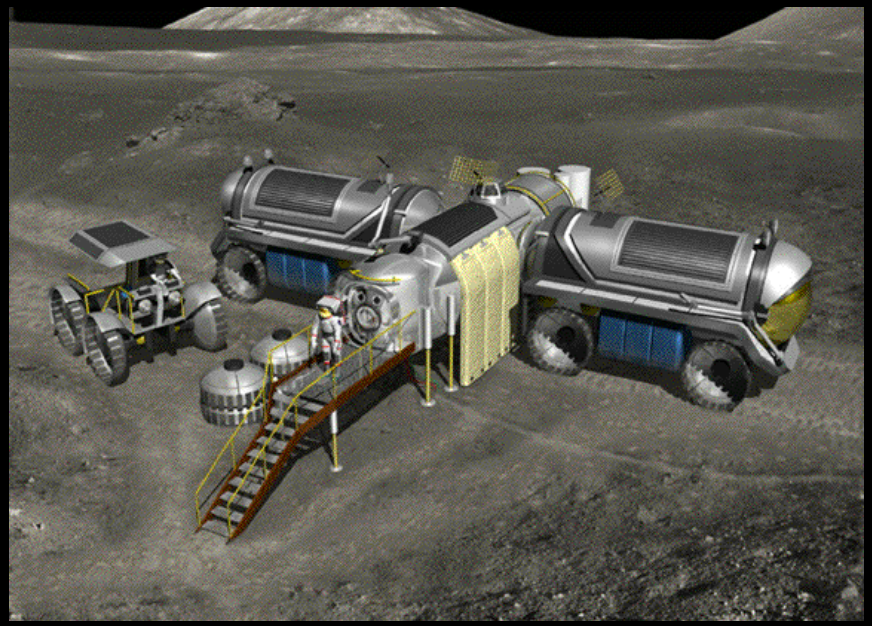
} Temp rise 0.7°C
Weather patterns, wildfires,
floods/droughts

Food?

T. Root, Stanford


Sustainability?
Population?
Affluence?
Species diversity?
Technology?





First flight test with sustainable biofuels for commercial aviation

NASA

First sustainable biofuel flight test in Asia

Scheduled 2009

First North American sustainable biofuel flight test

Scheduled 2009

Biofuels fly airplanes…

What about Biofuels?

Not use agricultural land

Not use freshwater or fertilizers

Feasible, affordable, scalable, sustainable…

NOW!


EXCUSE ME. I'M GOING TO NEED TWO TO PUSH MY CAR.

How **green** are biofuels?

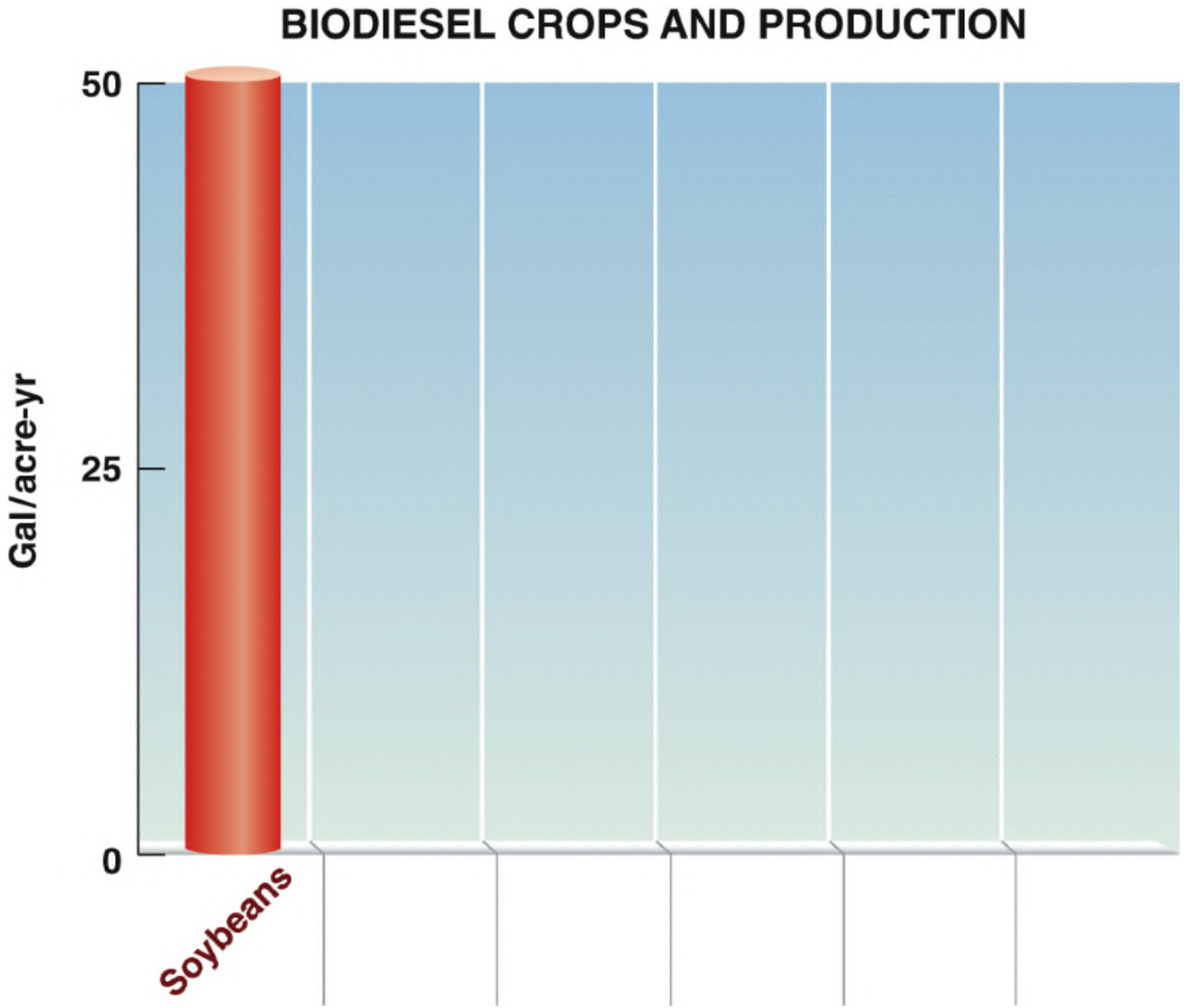
	Corn	Sugar Cane	Switch Grass
Product			
GHG output*			
Water			
Fertilizer			
Pesticide			
Energy			
US crop land/ half demand			

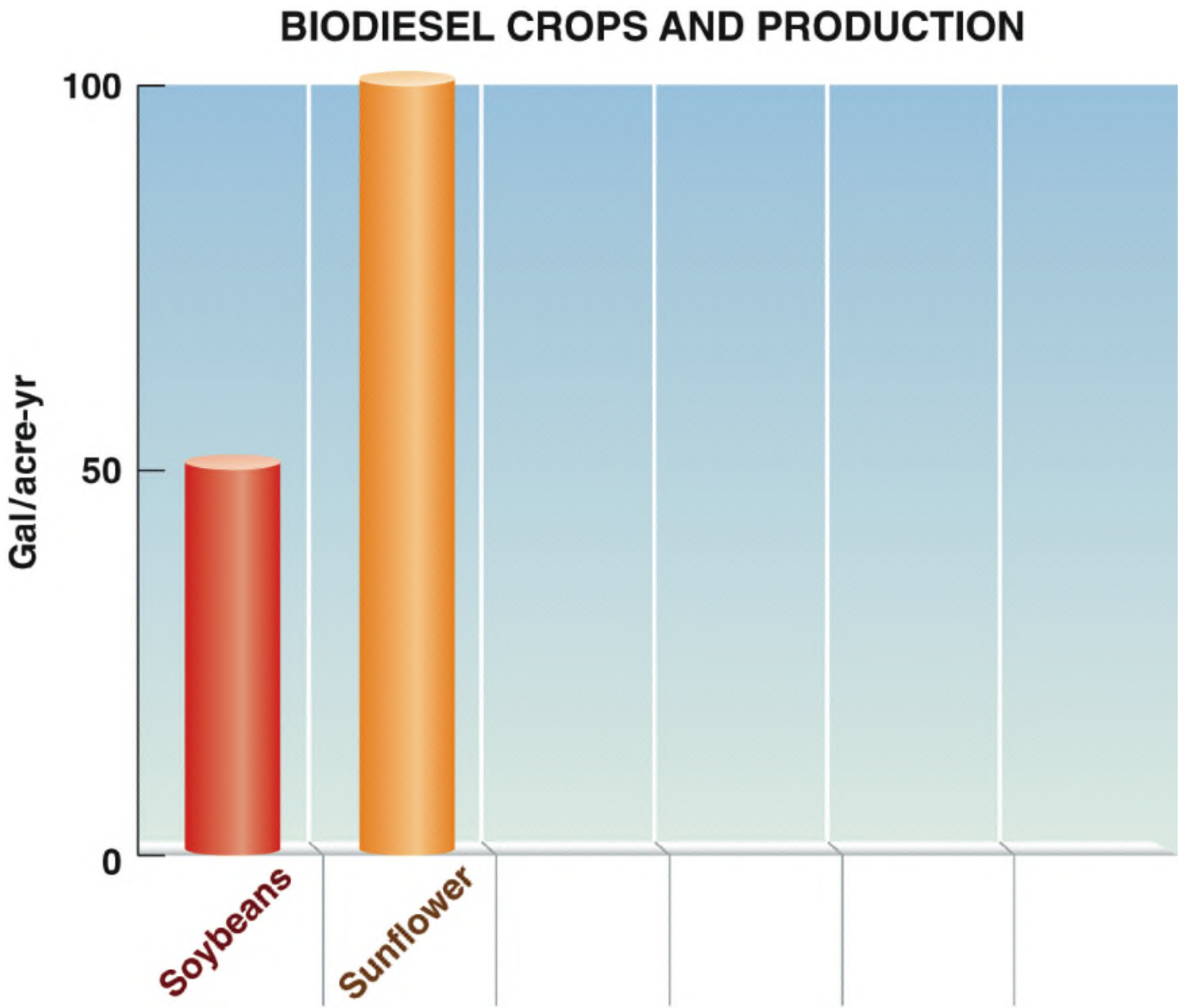
*CO_2 kg/MJ: Growing, harvesting, refining, burning fuel (cf., gas=94)

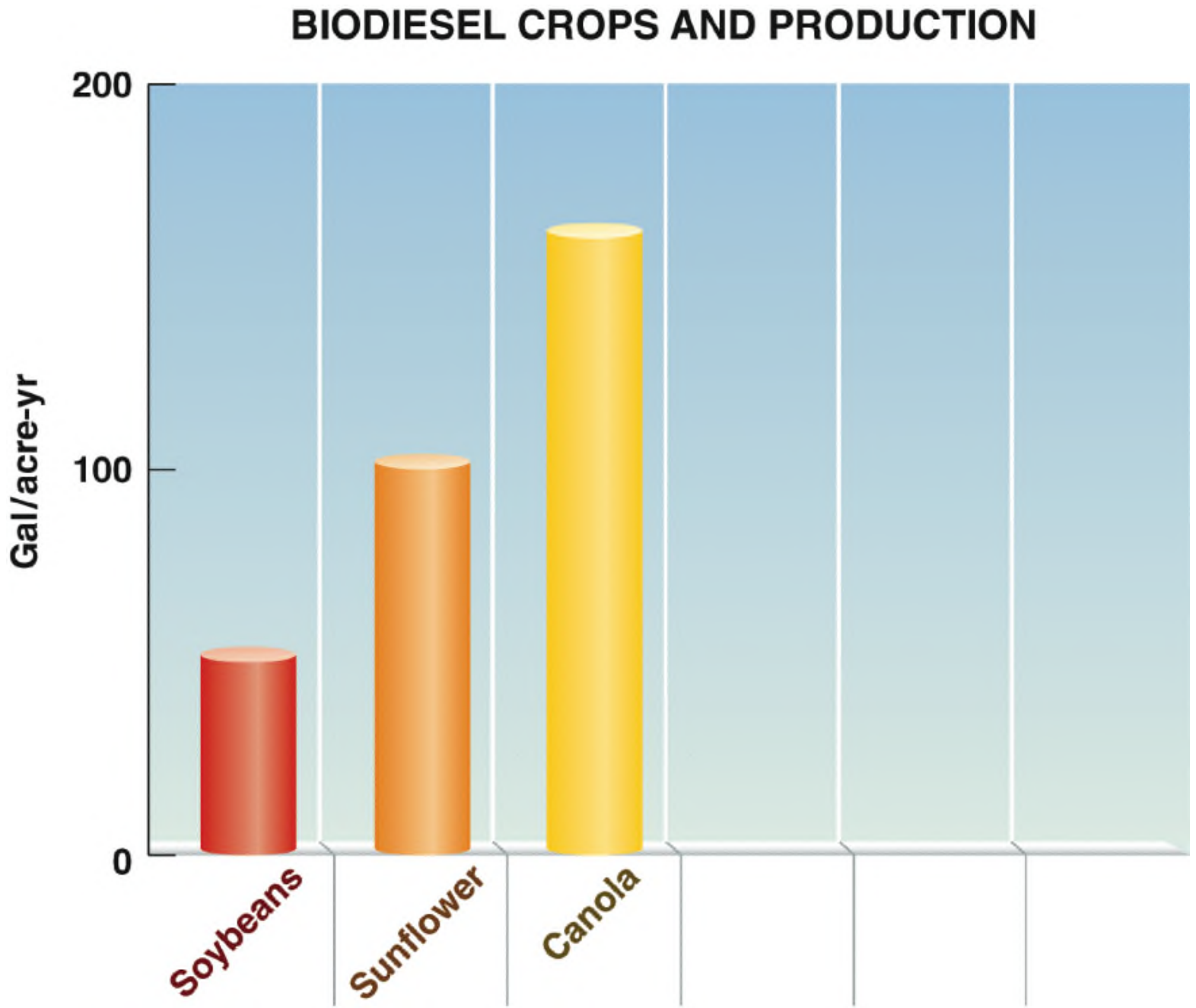
The problem with biodiesel…

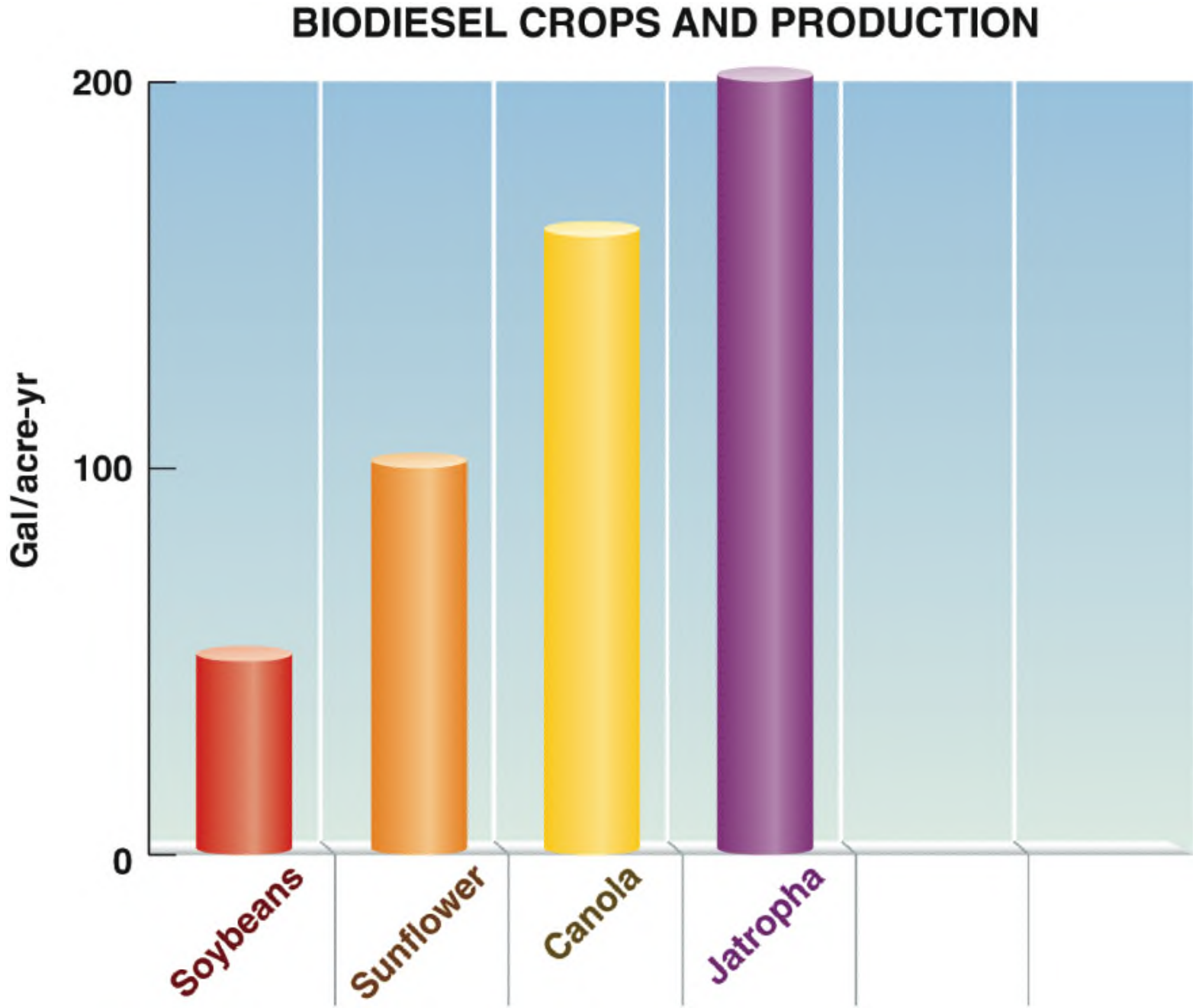
	Wood Residue	Soybeans	Rapeseed, Canola
Product	Ethanol, biodiesel	biodiesel	biodiesel
GHG output*	N/A	49	37
Water	low	HIGH	HIGH
Fertilizer	low	low-med	med
Pesticide	low	med	med
Energy	low	med-low	med-low
US crop land/ half demand	150 -250%	180-240%	30%

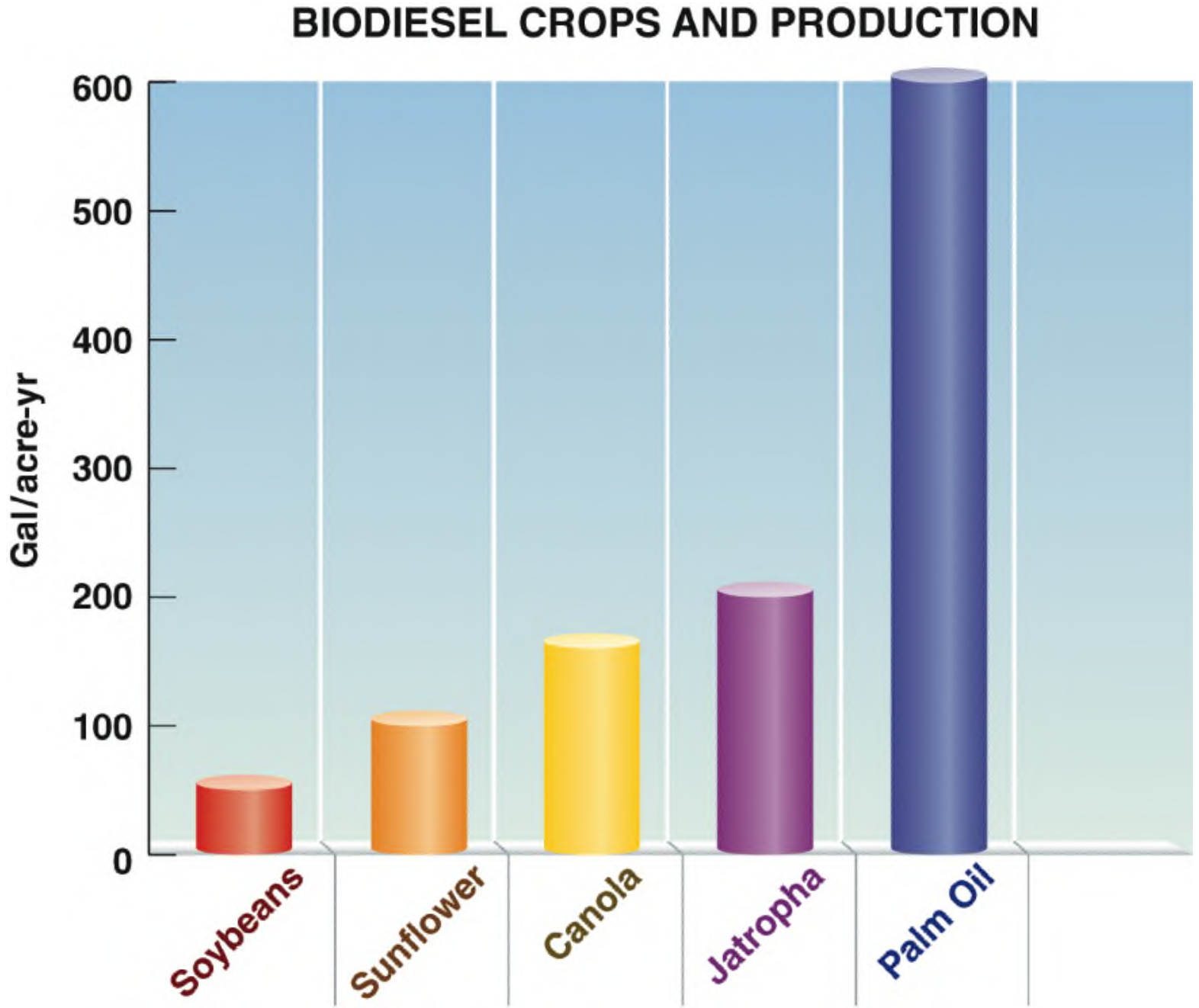
*CO_2 kg/MJ: Growing, harvesting, refining, burning fuel (cf., Diesel=83)

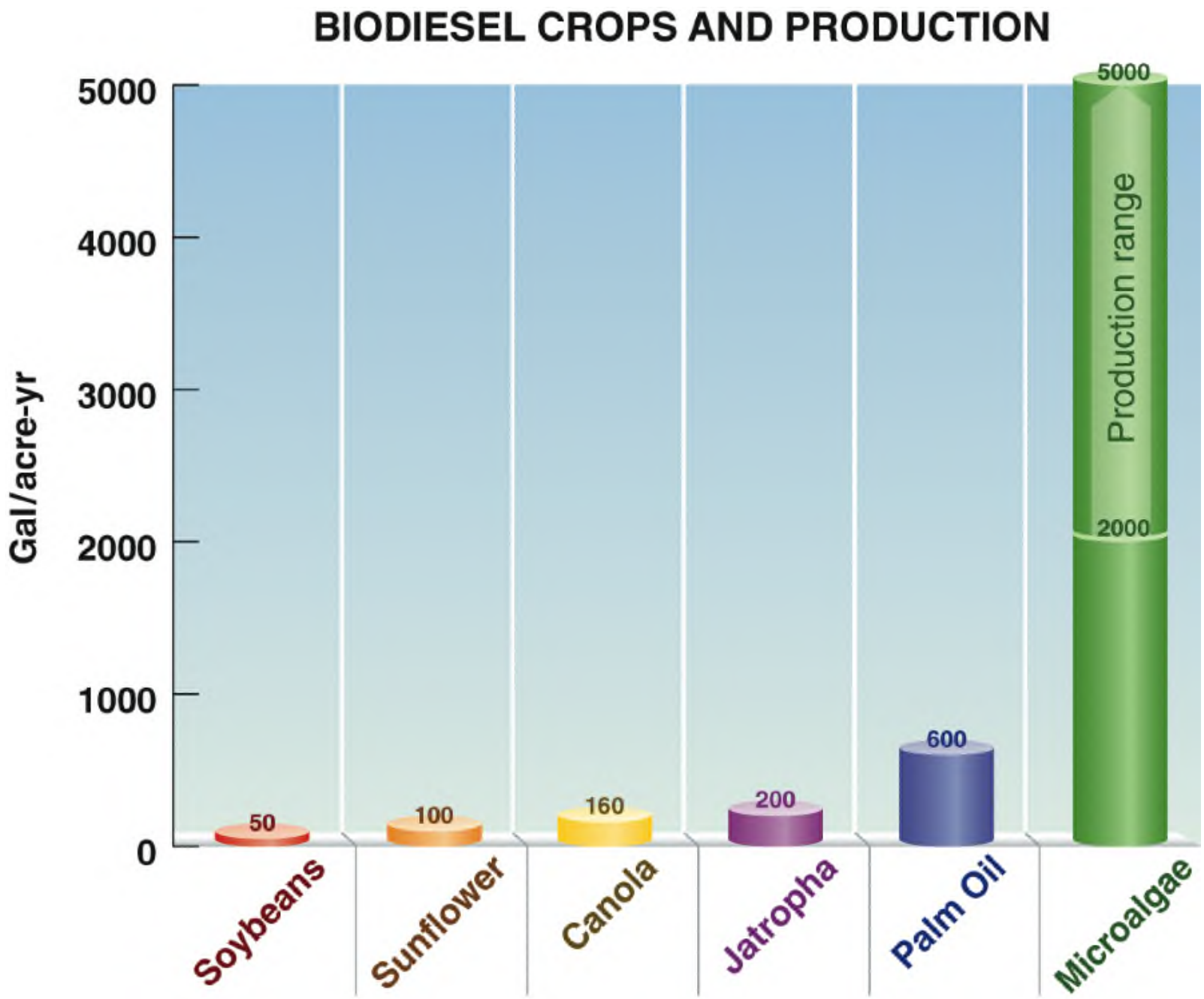

BIODIESEL CROPS AND PRODUCTION
50
25
0
Gal/acre-yr
Soybeans

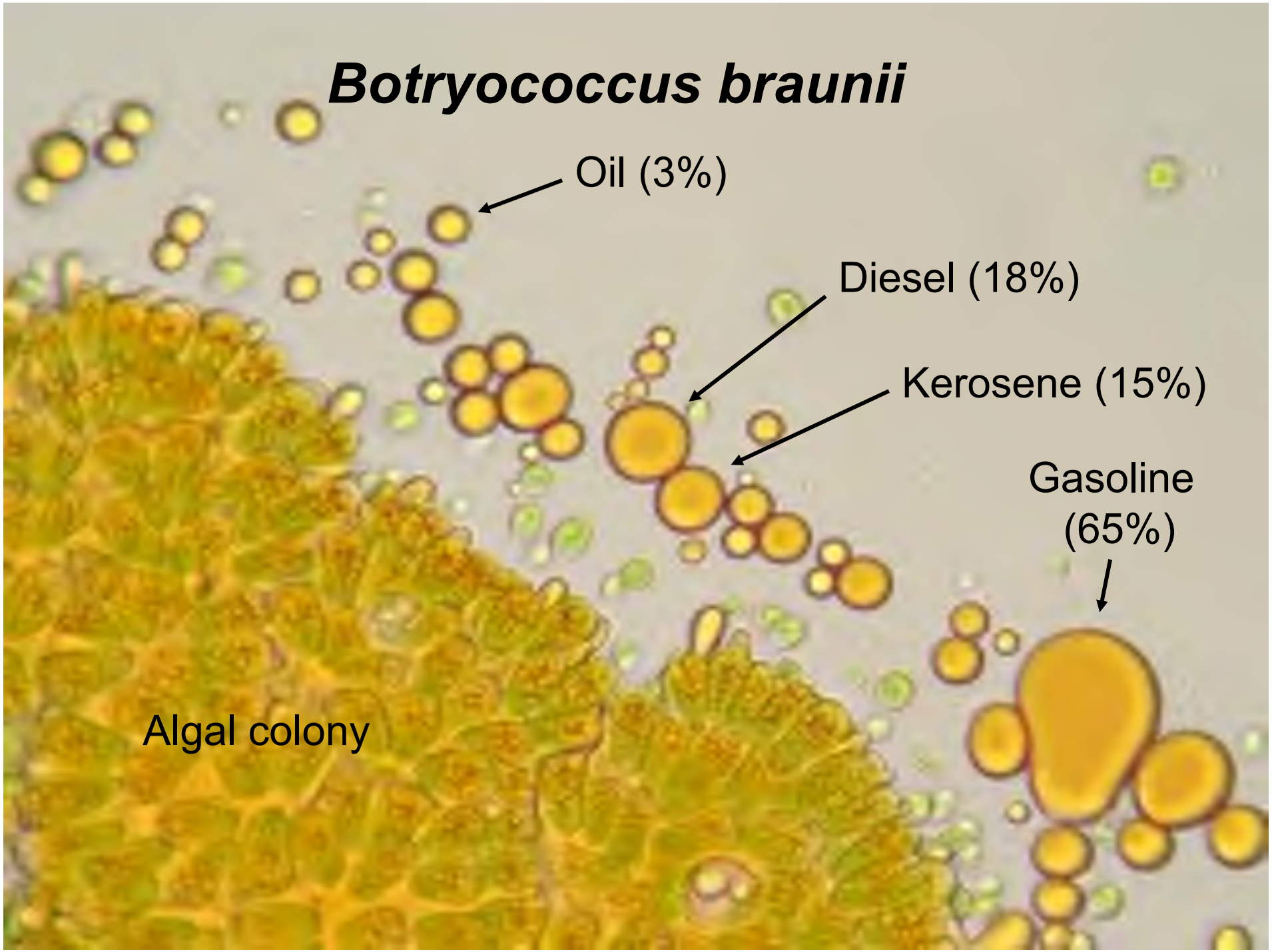

BIODIESEL CROPS AND PRODUCTION
100
50
0
Gal/acre-yr
Soybeans
Sunflower


BIODIESEL CROPS AND PRODUCTION
200
100
0
Gal/acre-yr
Soybeans
Sunflower
Canola


BIODIESEL CROPS AND PRODUCTION
Gal/acre-yr
200
100
0
Soybeans
Sunflower
Canola
Jatropha


BIODIESEL CROPS AND PRODUCTION
Gal/acre-yr
600
500
400
300
200
100
0
Soybeans
Sunflower
Canola
Jatropha
Palm Oil


BIODIESEL CROPS AND PRODUCTION
Gal/acre-yr
5000
4000
3000
2000
1000
0
50
100
160
200
600
5000
2000
Production range
Soybeans
Sunflower
Canola
Jatropha
Palm Oil
Microalgae

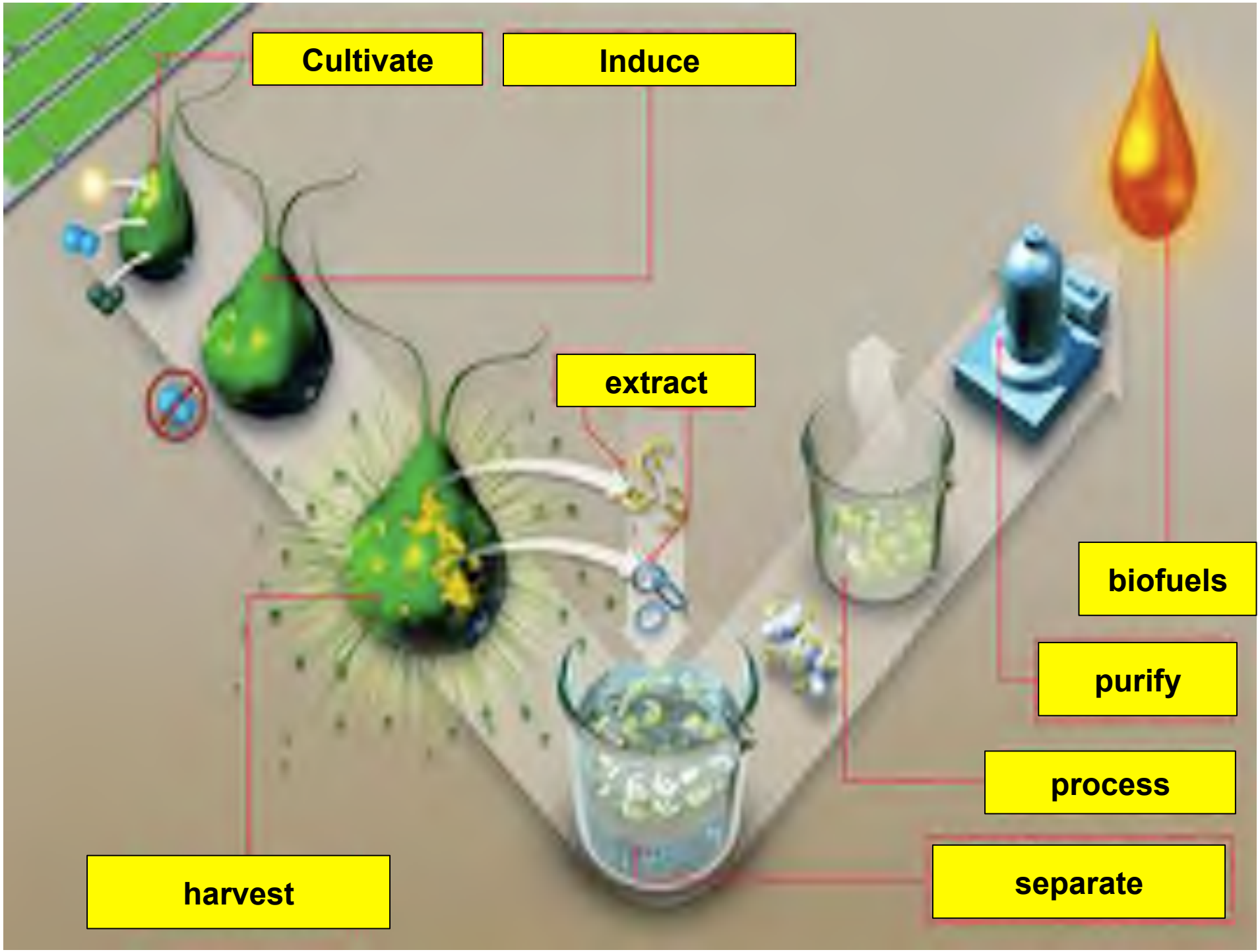

Botryococcus braunii
Oil (3%)
Diesel (18%)
Kerosene (15%)
Gasoline (65%)
Algal colony


CANADA
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
HAWAII
ALASKA
MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
THE BAHAMAS

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 !

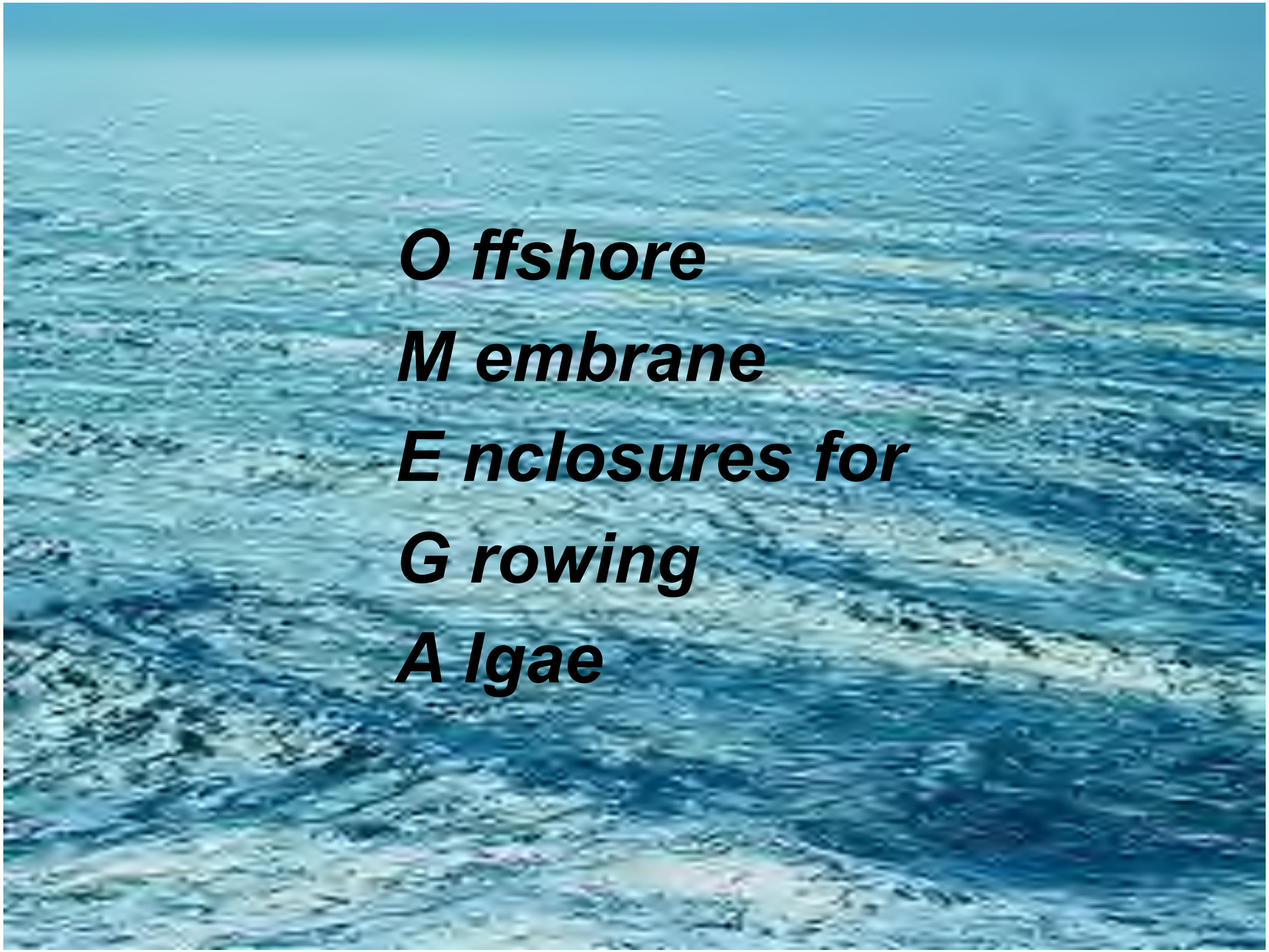

Cultivate
Induce
extract
biofuels
purify
process
separate
harvest

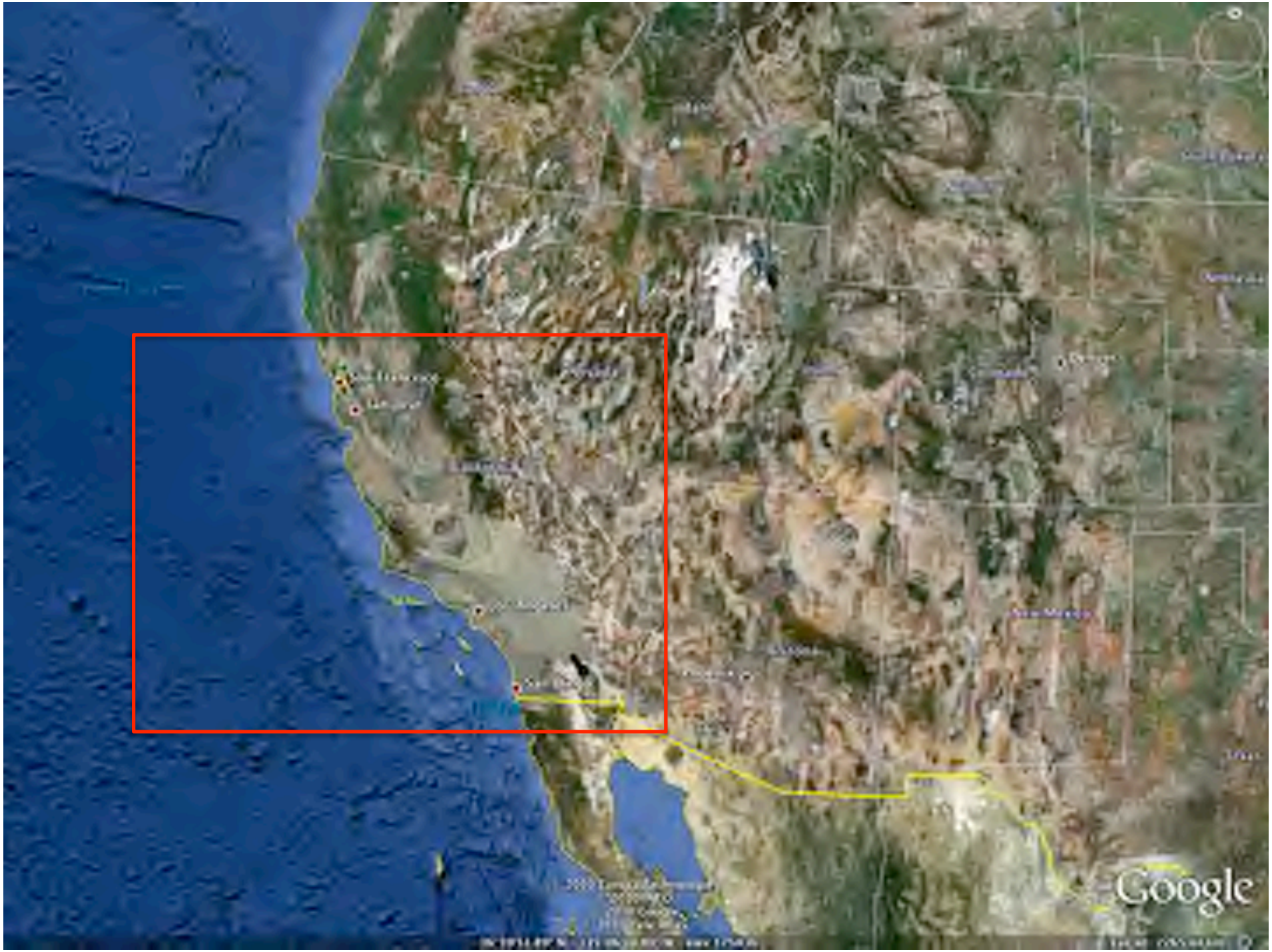
There are challenges growing algae on land…

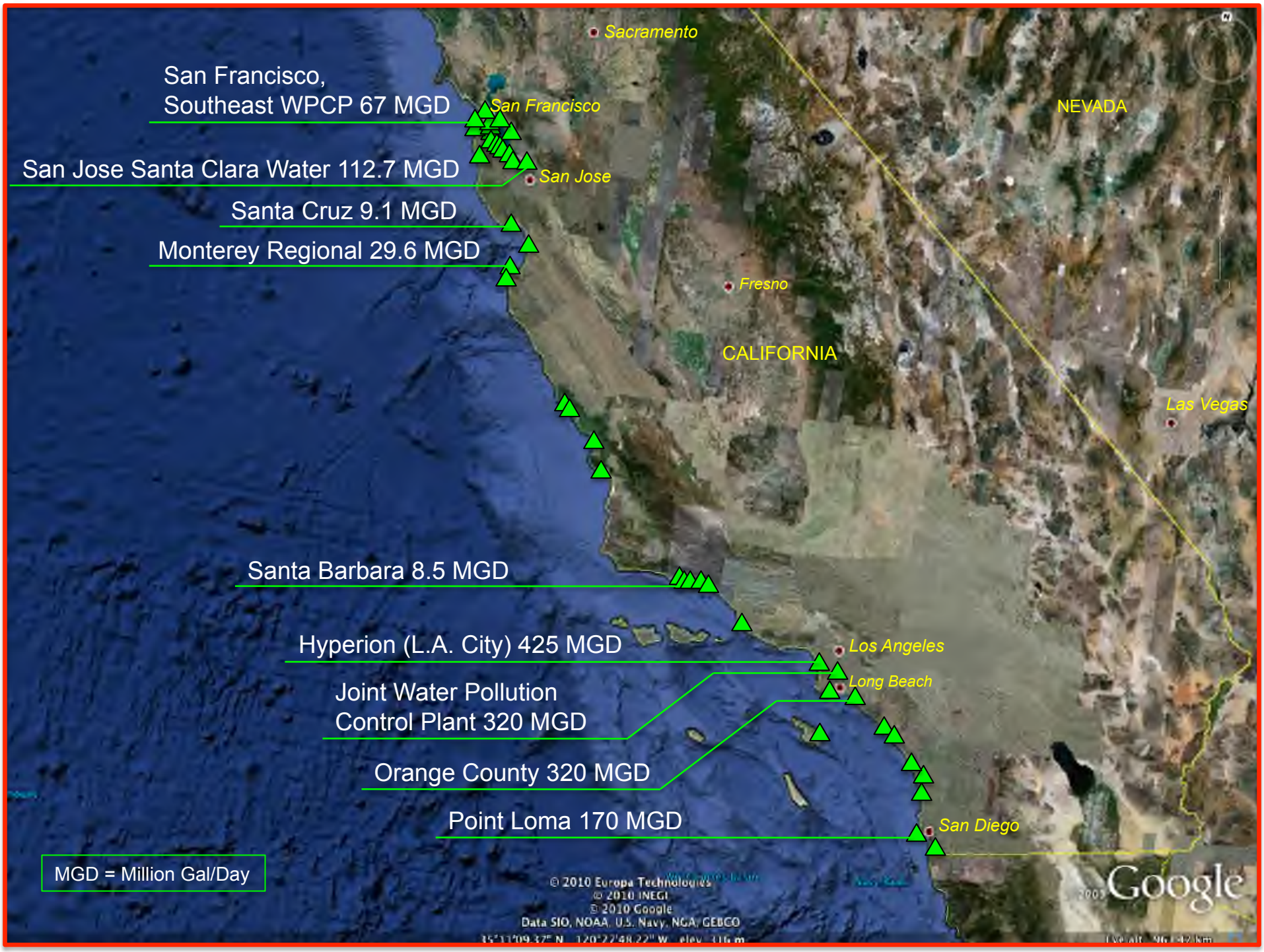
Open circulating ponds (raceways)

Closed photobioreactors (PBRs)


What about growing algae
in the ocean?


O ffshore
M embrane
E nclosures for
G rowing
A lgae


Google


Sacramento
San Francisco,
Southeast WPCP 67 MGD
San Francisco
NEVADA
San Jose Santa Clara Water 112.7 MGD
San Jose
Santa Cruz 9.1 MGD
Monterey Regional 29.6 MGD
Fresno
CALIFORNIA
Las Vegas
Santa Barbara 8.5 MGD
Hyperion (L.A. City) 425 MGD
Los Angeles
Long Beach
Joint Water Pollution
Control Plant 320 MGD
Orange County 320 MGD
Point Loma 170 MGD
San Diego
MGD = Million Gal/Day
© 2010 Europa Technologies
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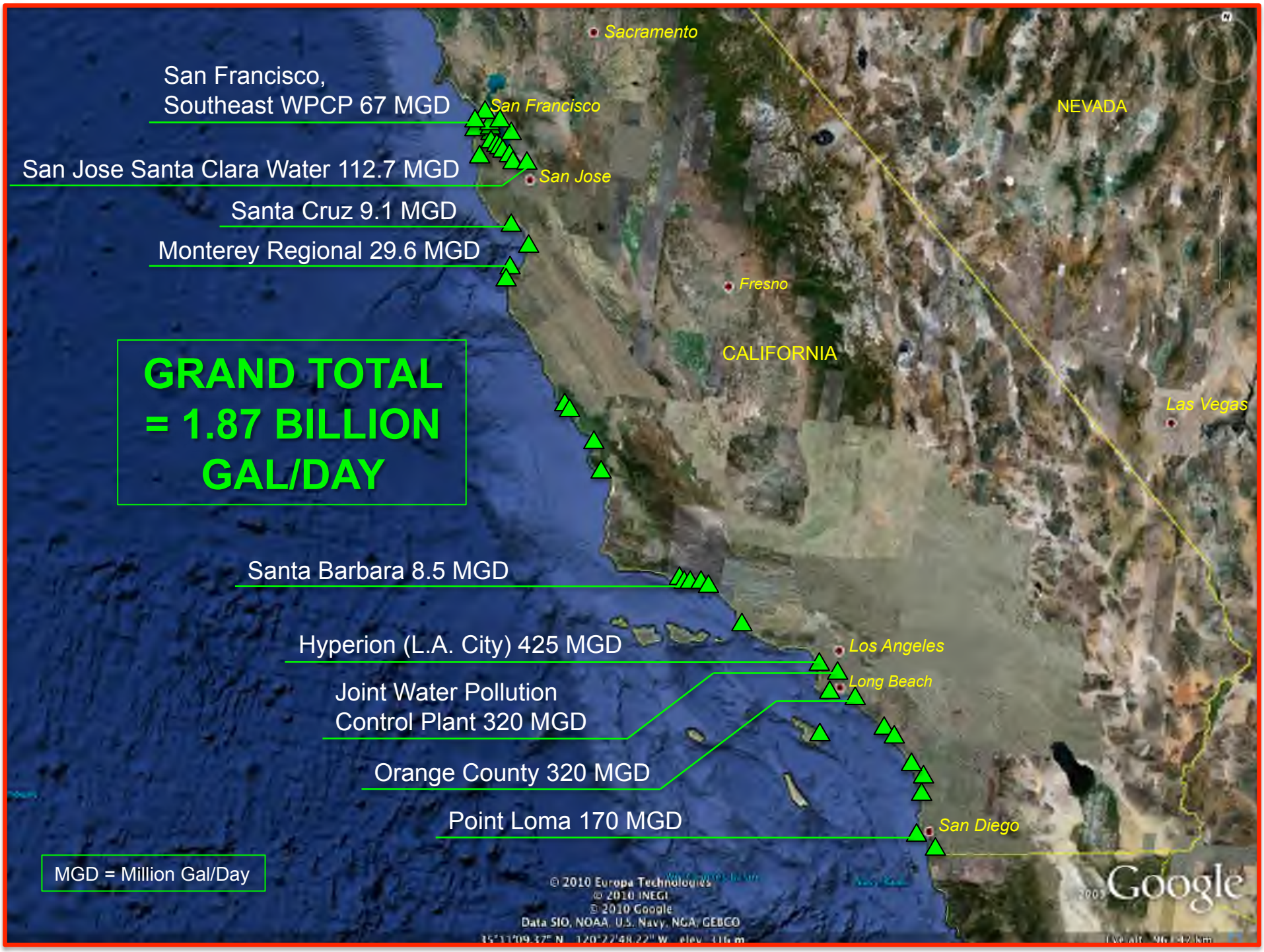
© 2010 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google


Sacramento
San Francisco,
Southeast WPCP 67 MGD
San Francisco
NEVADA
San Jose Santa Clara Water 112.7 MGD
San Jose
Santa Cruz 9.1 MGD
Monterey Regional 29.6 MGD
Fresno
CALIFORNIA
GRAND TOTAL
= 1.87 BILLION
GAL/DAY
Las Vegas
Santa Barbara 8.5 MGD
Hyperion (L.A. City) 425 MGD
Los Angeles
Long Beach
Joint Water Pollution
Control Plant 320 MGD
Orange County 320 MGD
Point Loma 170 MGD
San Diego
MGD = Million Gal/Day
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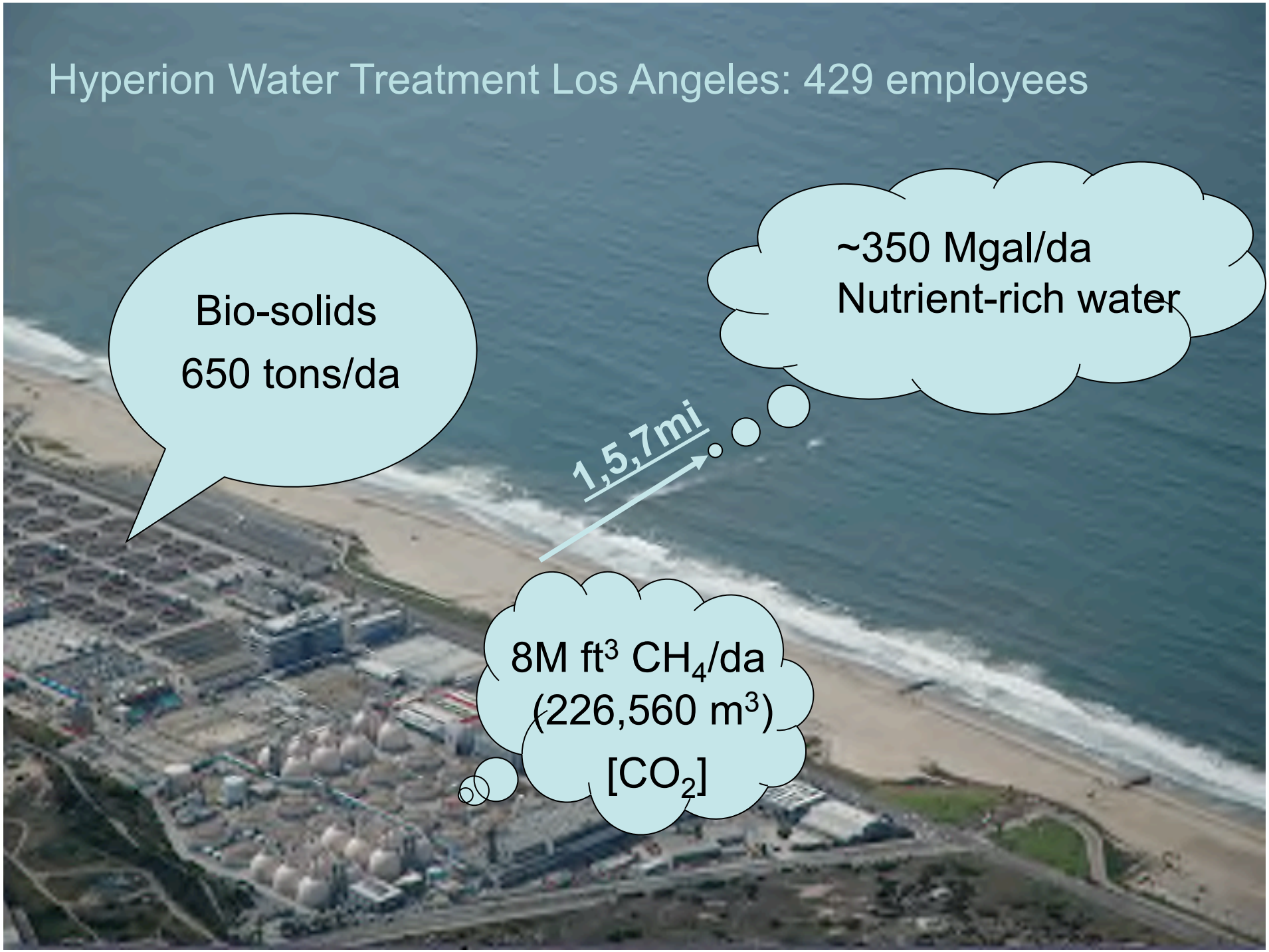
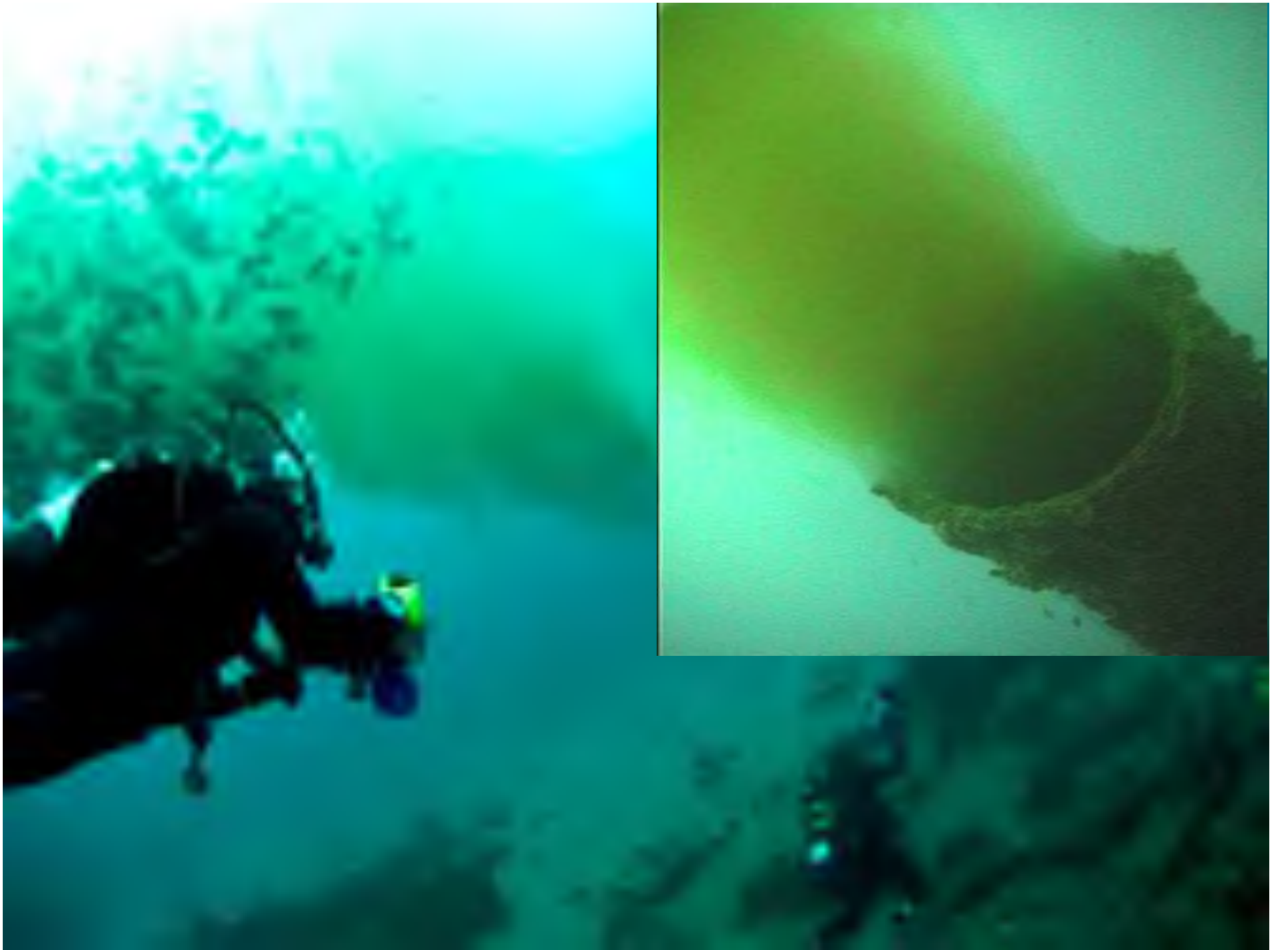
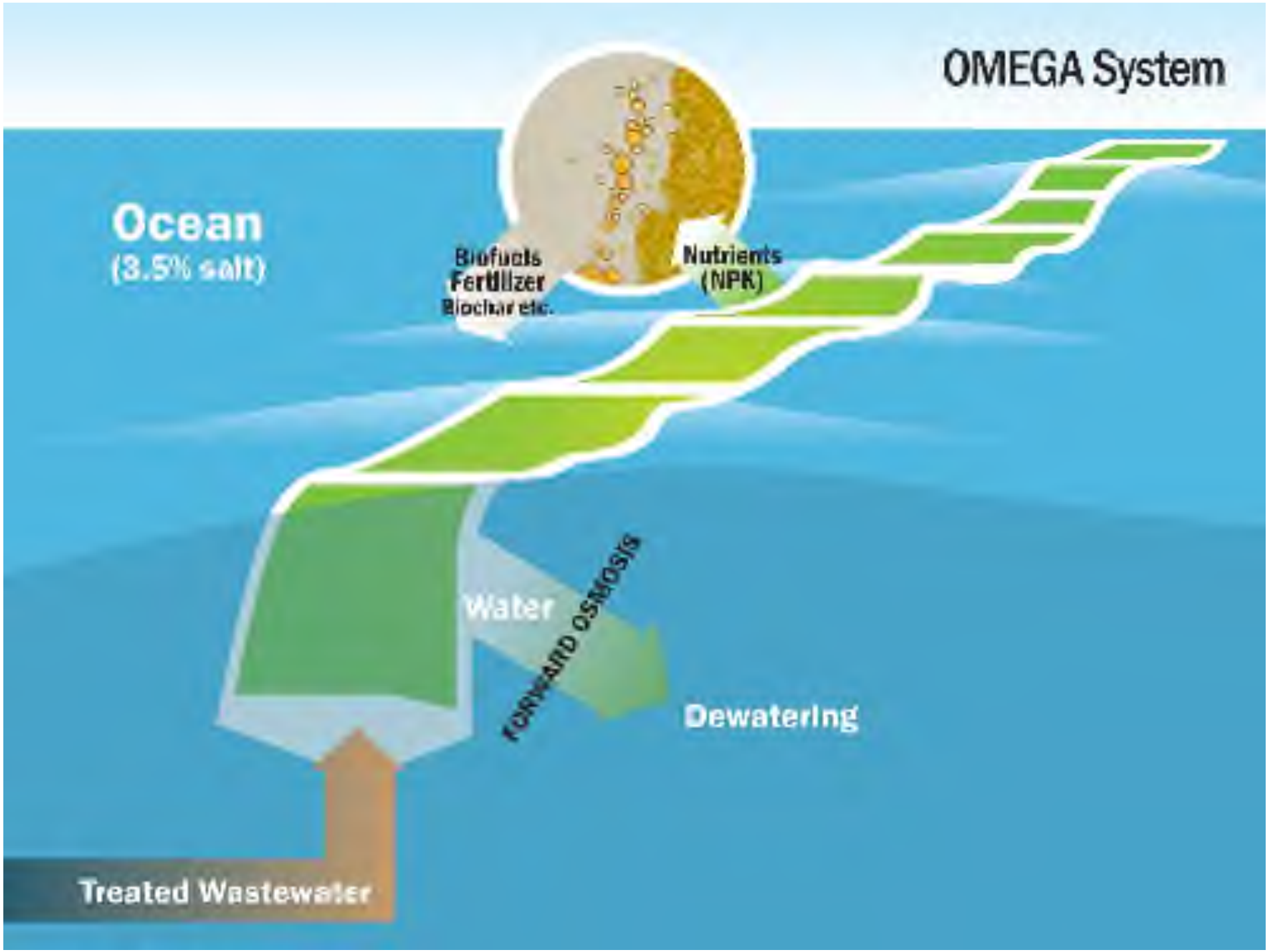
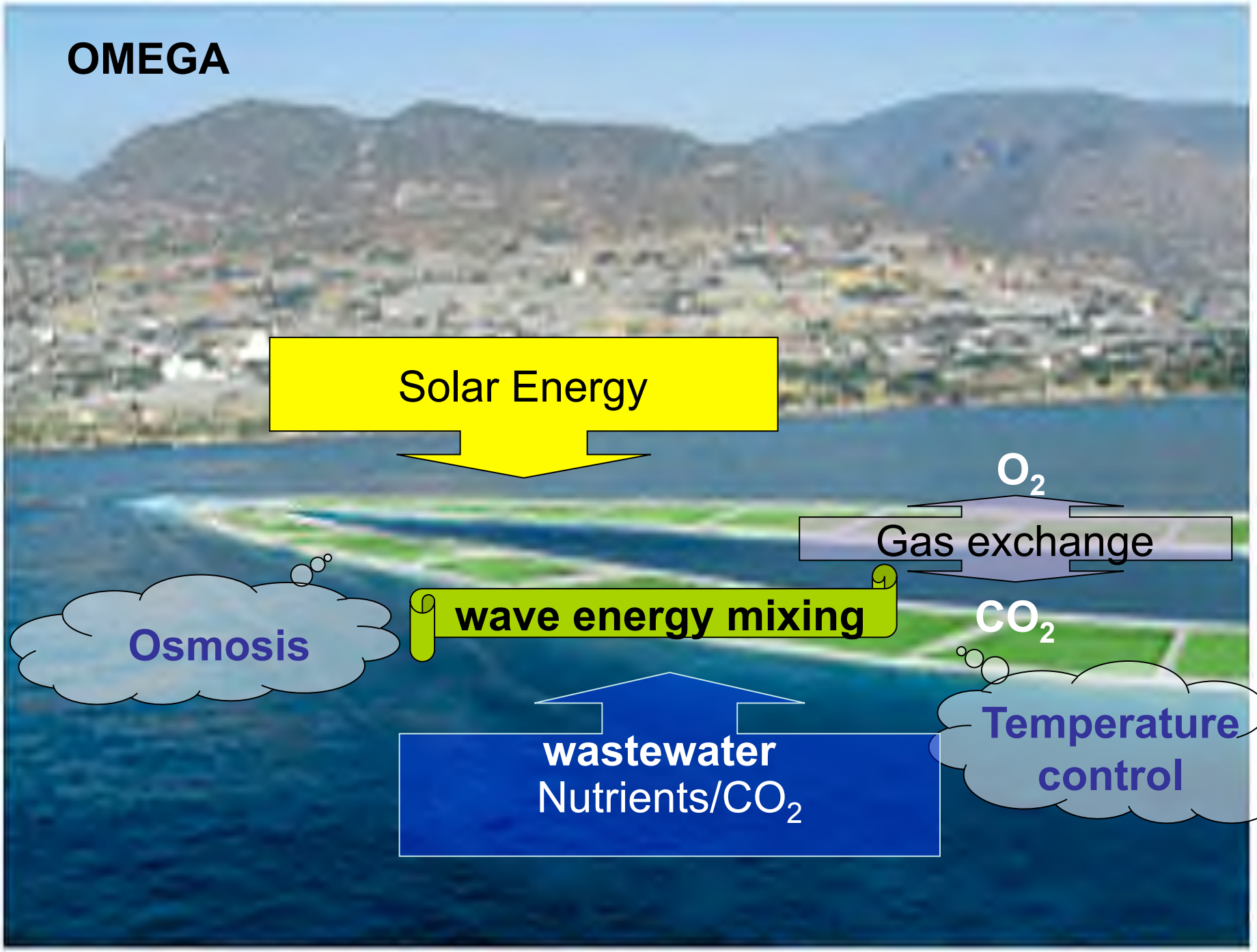
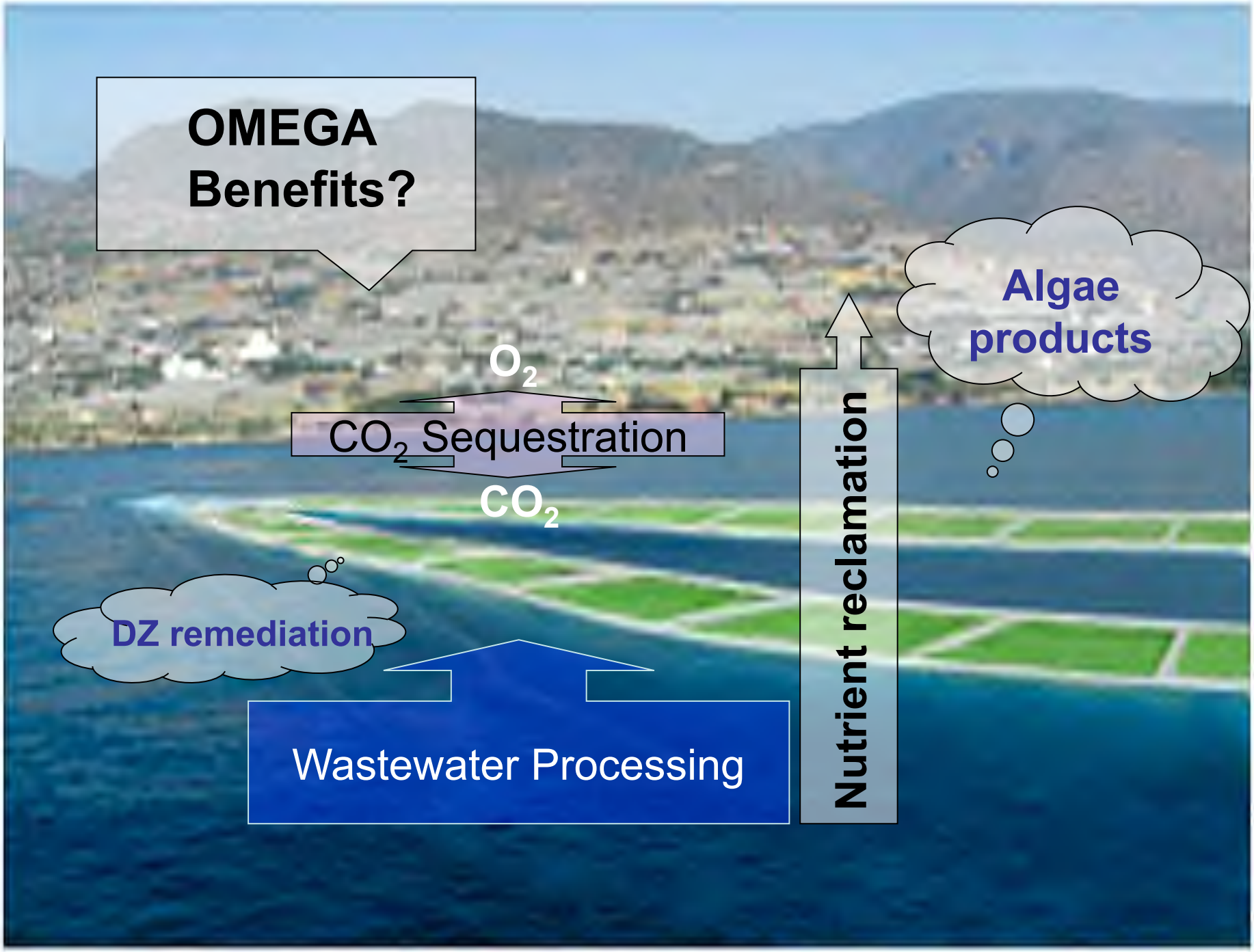
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google

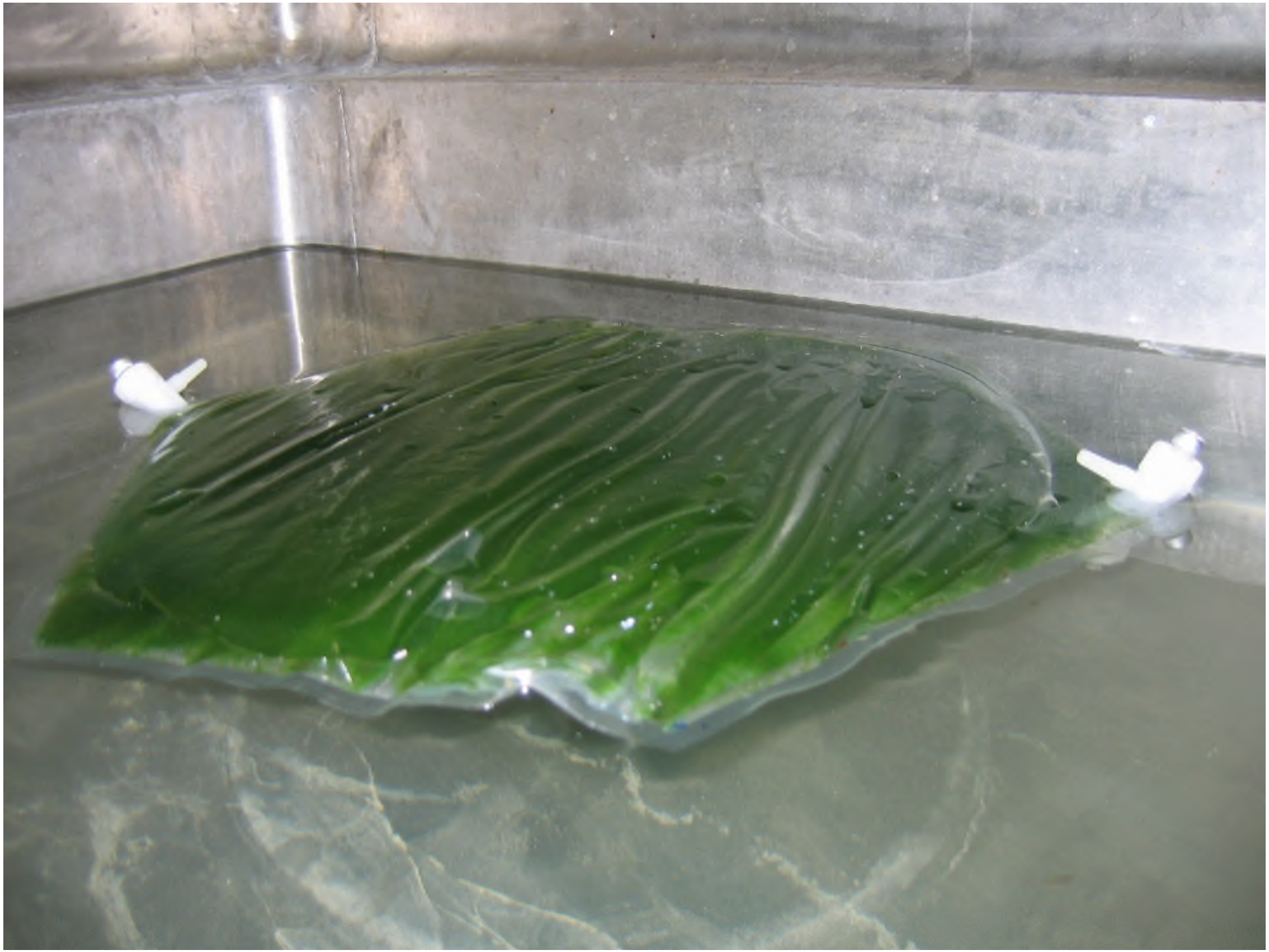

Hyperion Water Treatment Los Angeles: 429 employees
Bio-solids
650 tons/da
~350 Mgal/da
Nutrient-rich water
1,5,7mi
8M ft³ CH₄/da
(226,560 m³)
[CO₂]

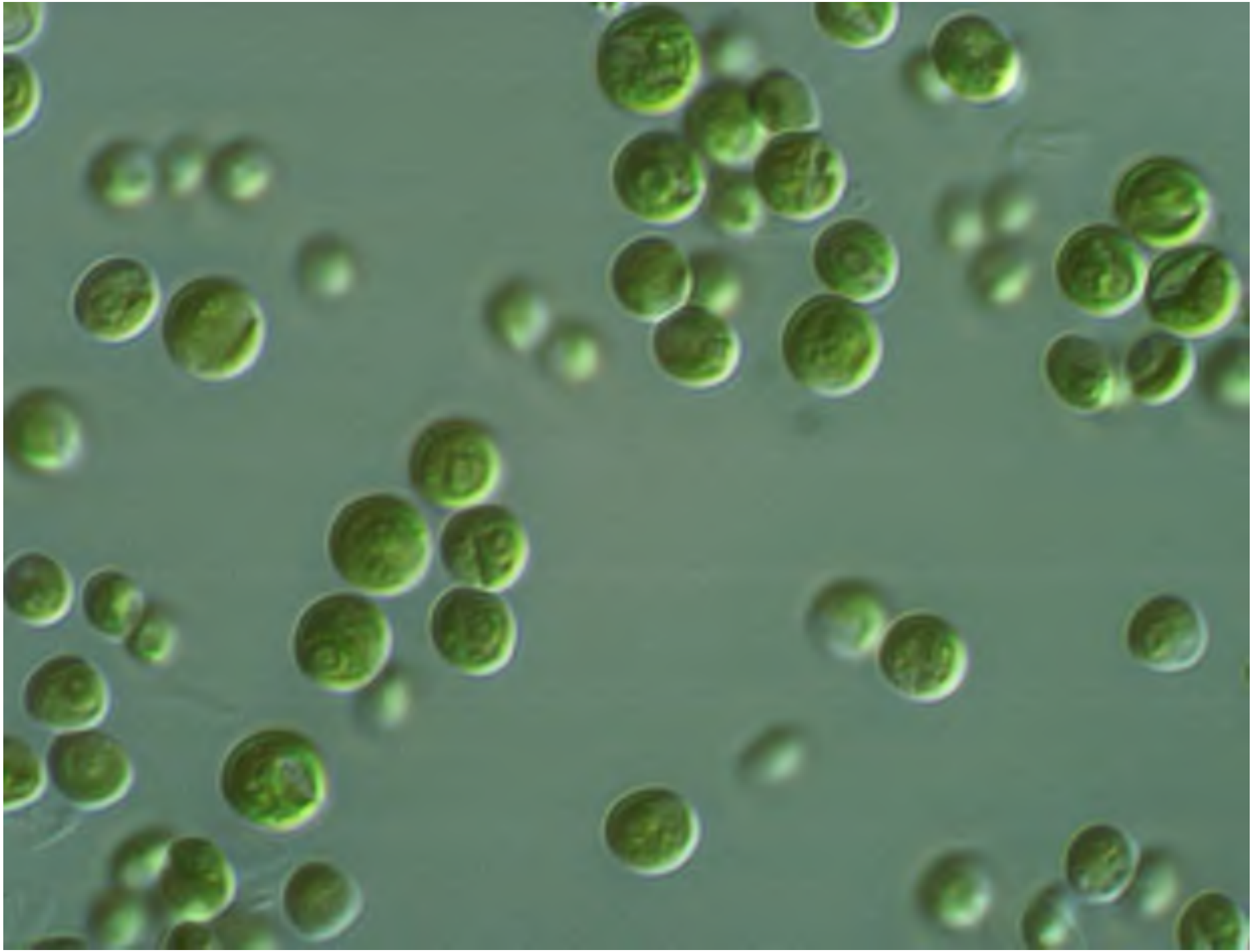


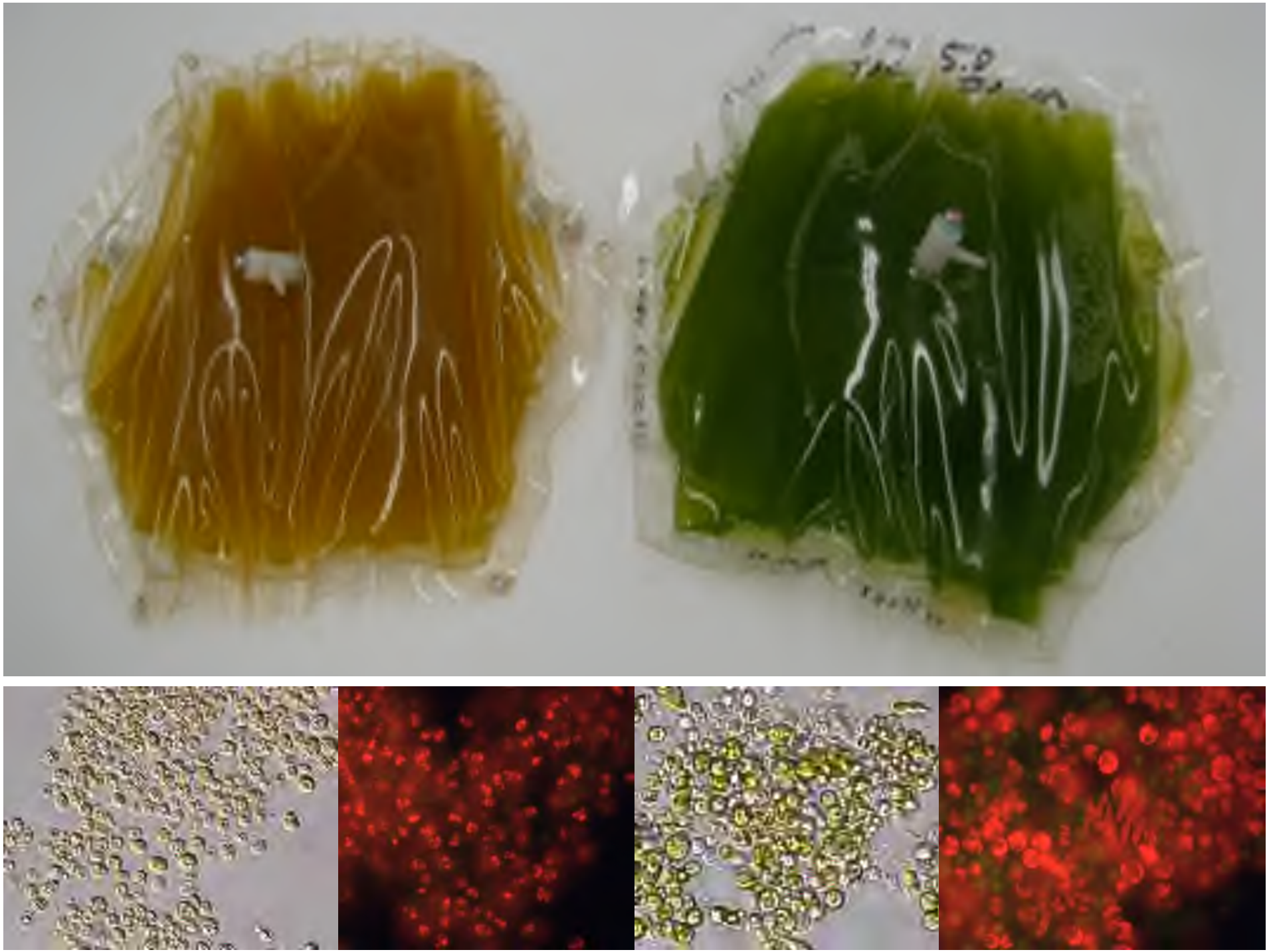

OMEGA System
Ocean
(3.5% salt)
Biofuels
Fertilizer
Biochar etc.
Nutrients
(NPK)
Water
FORWARD OSMOSIS
Dewatering
Treated Wastewater


OMEGA
Solar Energy
O_2
Gas exchange
wave energy mixing
Osmosis
CO_2
Temperature control
wastewater
Nutrients/CO_2

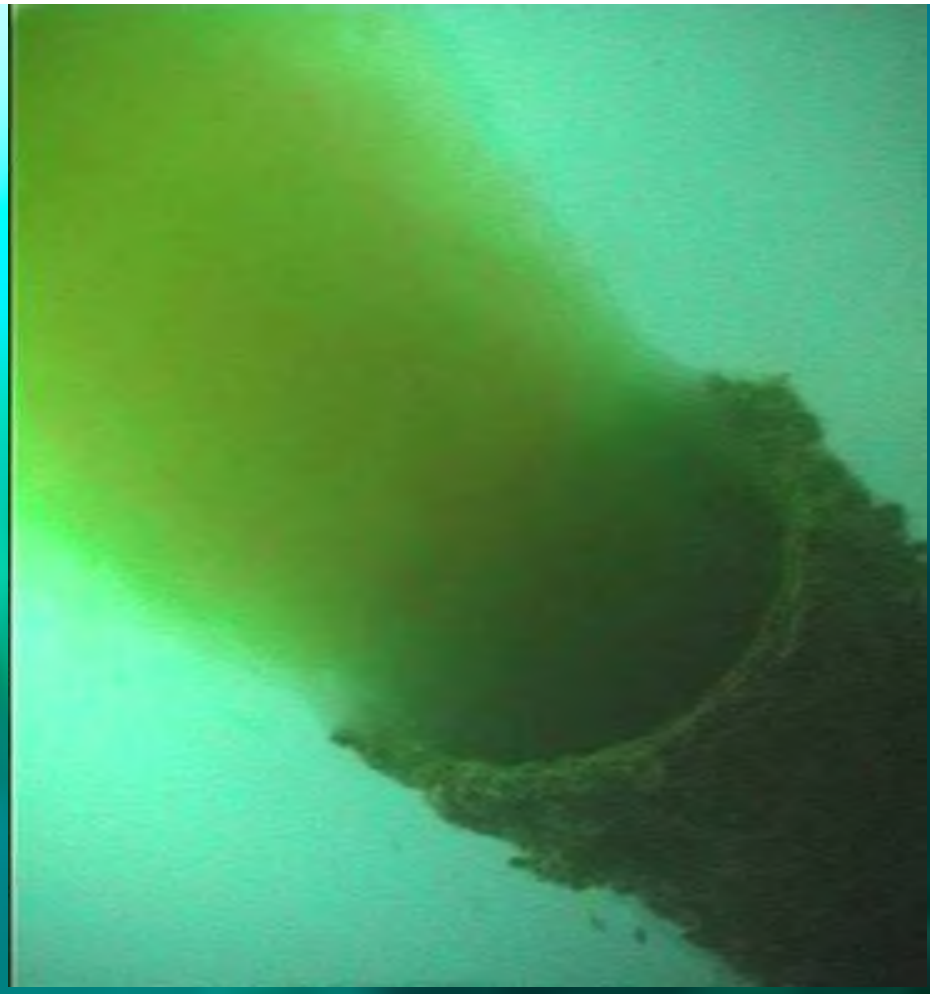

OMEGA
Benefits?
Algae
products
O_2
CO_2 Sequestration
CO_2
Nutrient reclamation
DZ remediation
Wastewater Processing

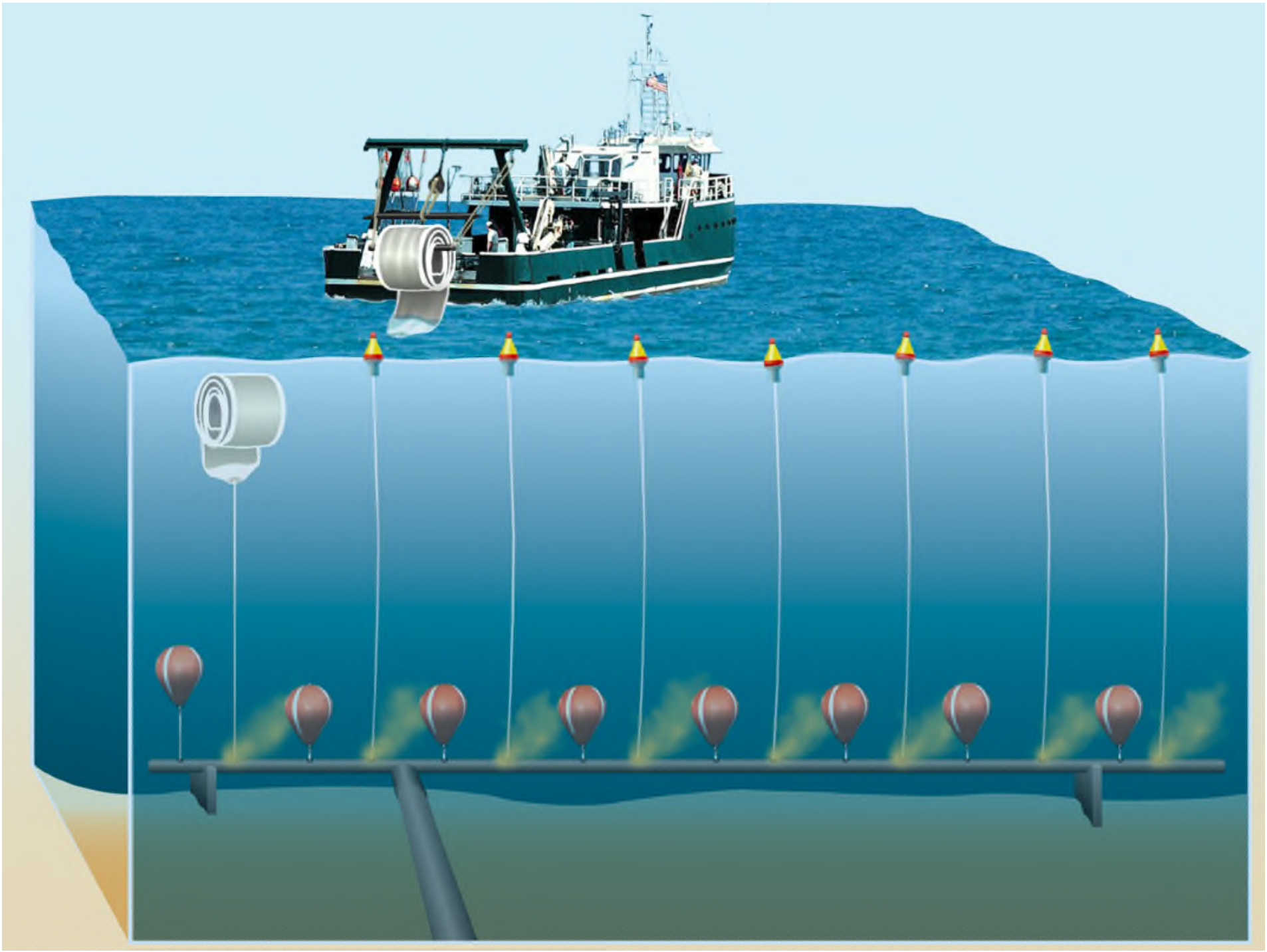


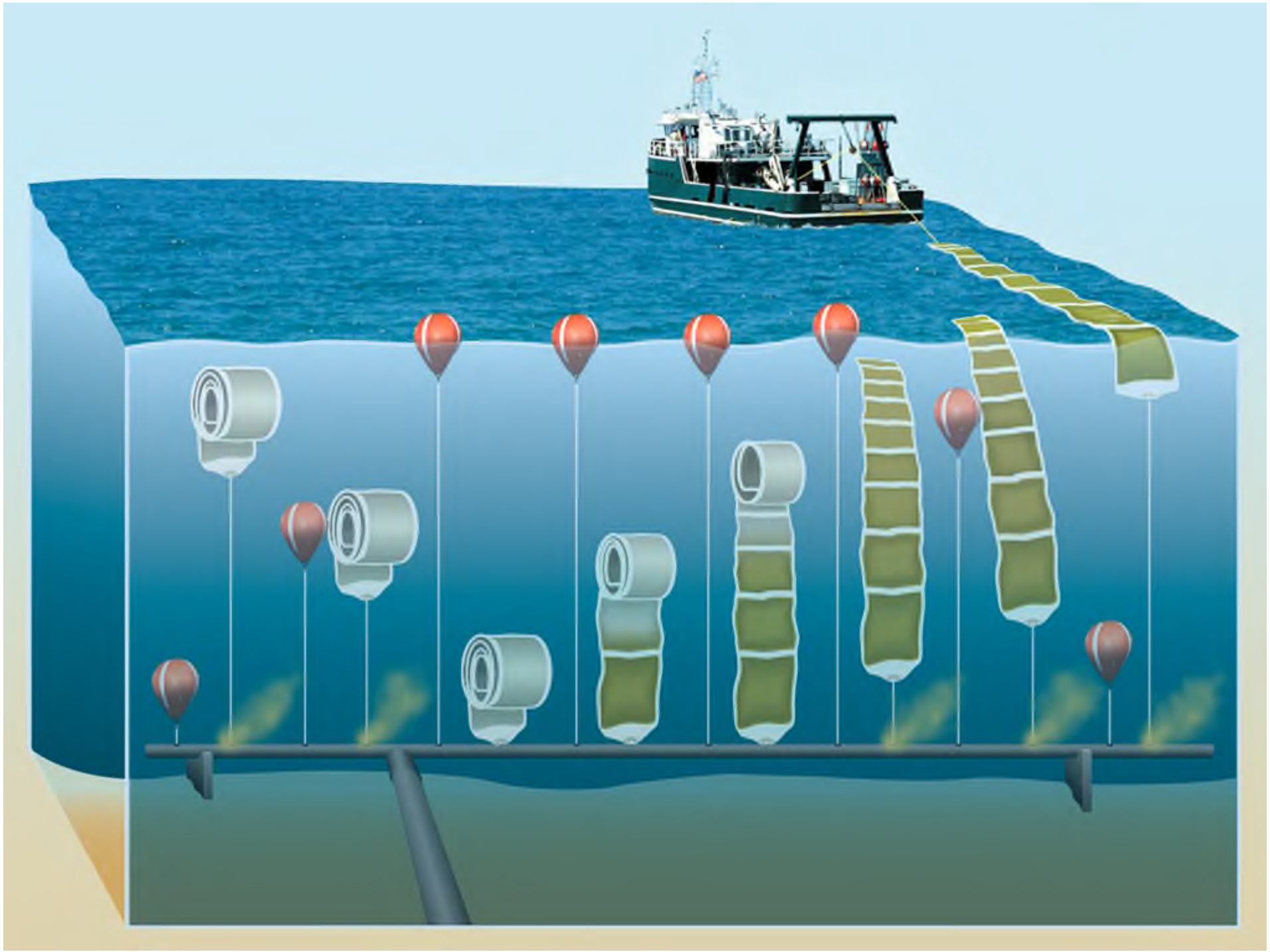


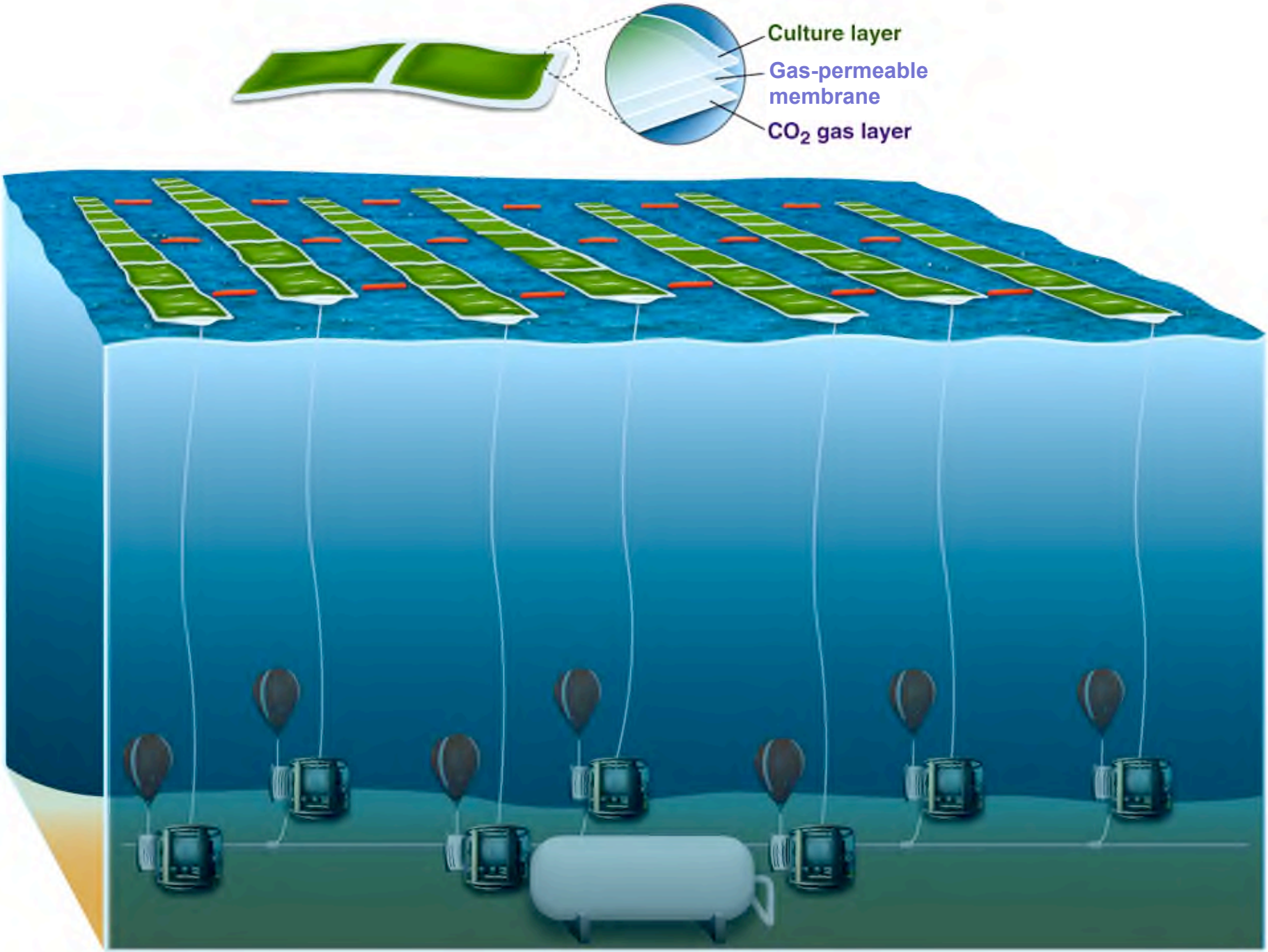


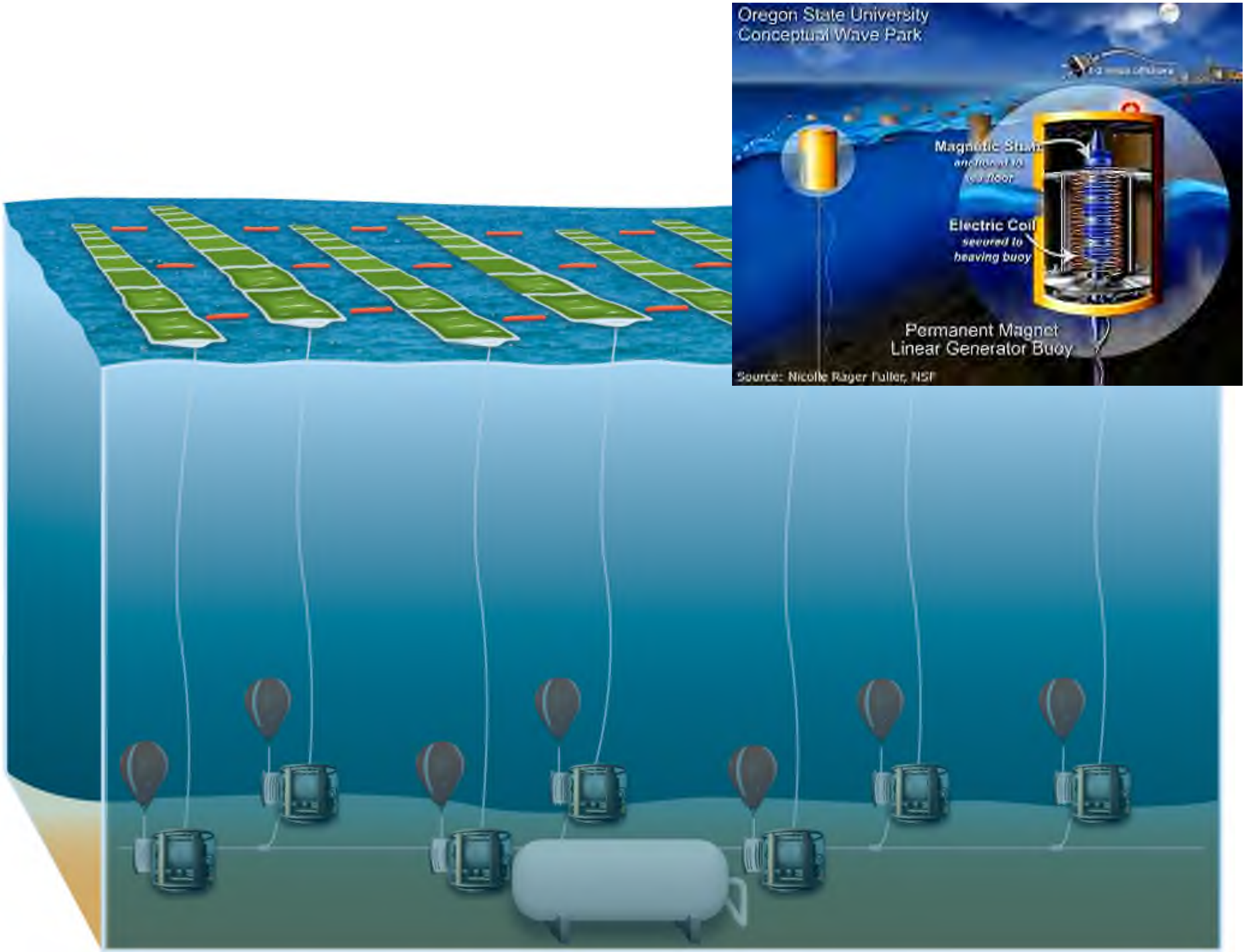
OMEGA logistics?

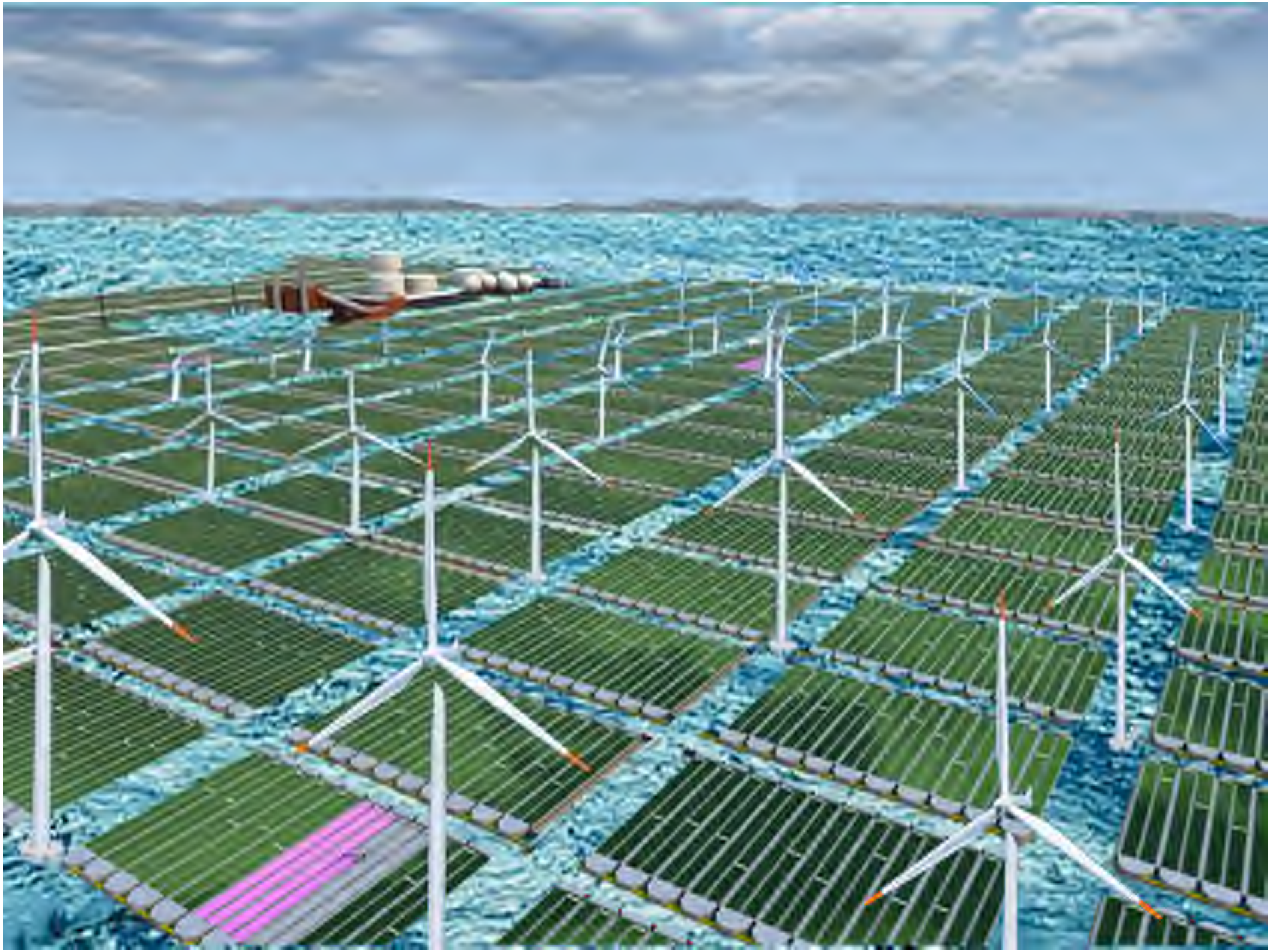


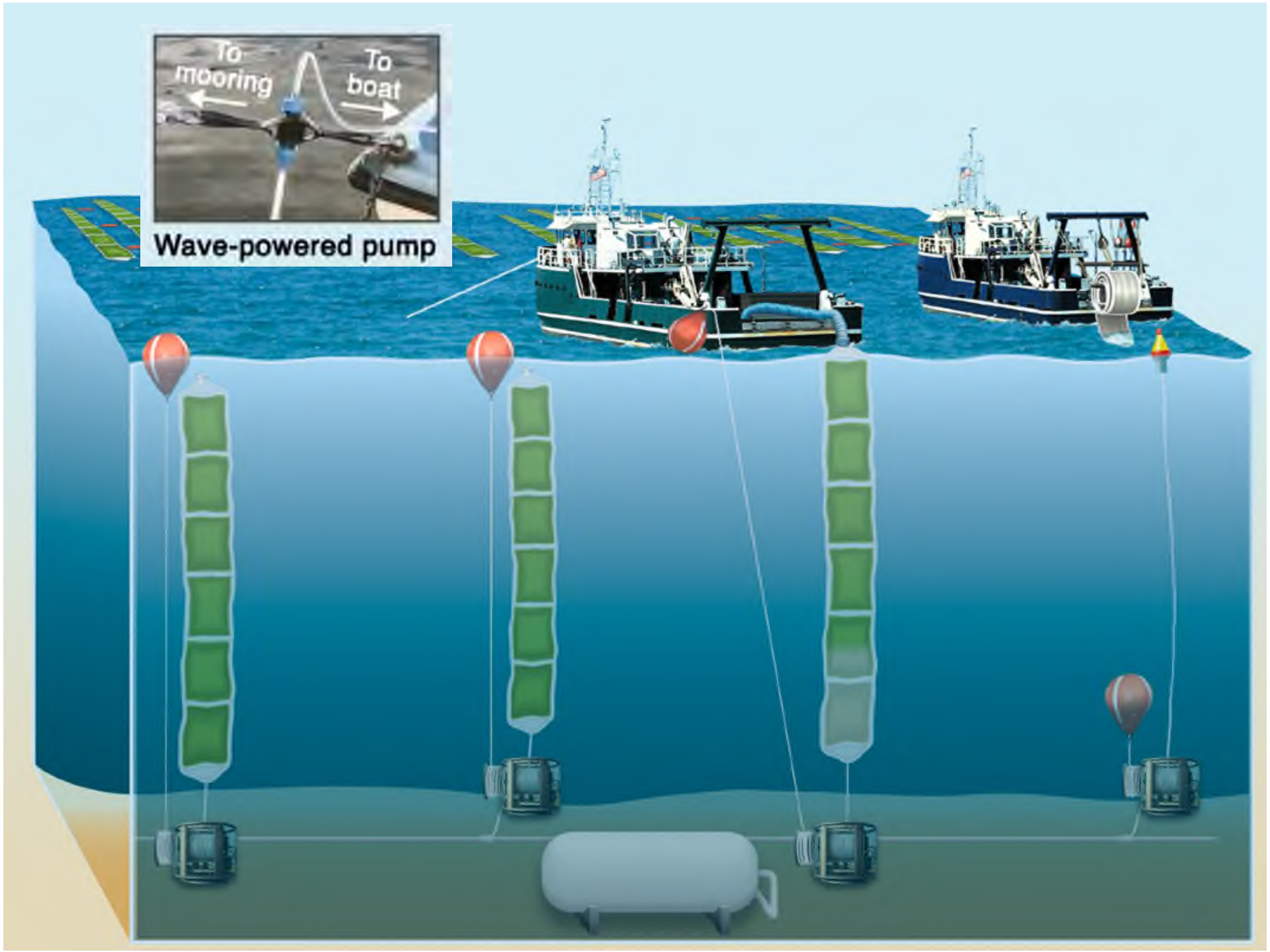


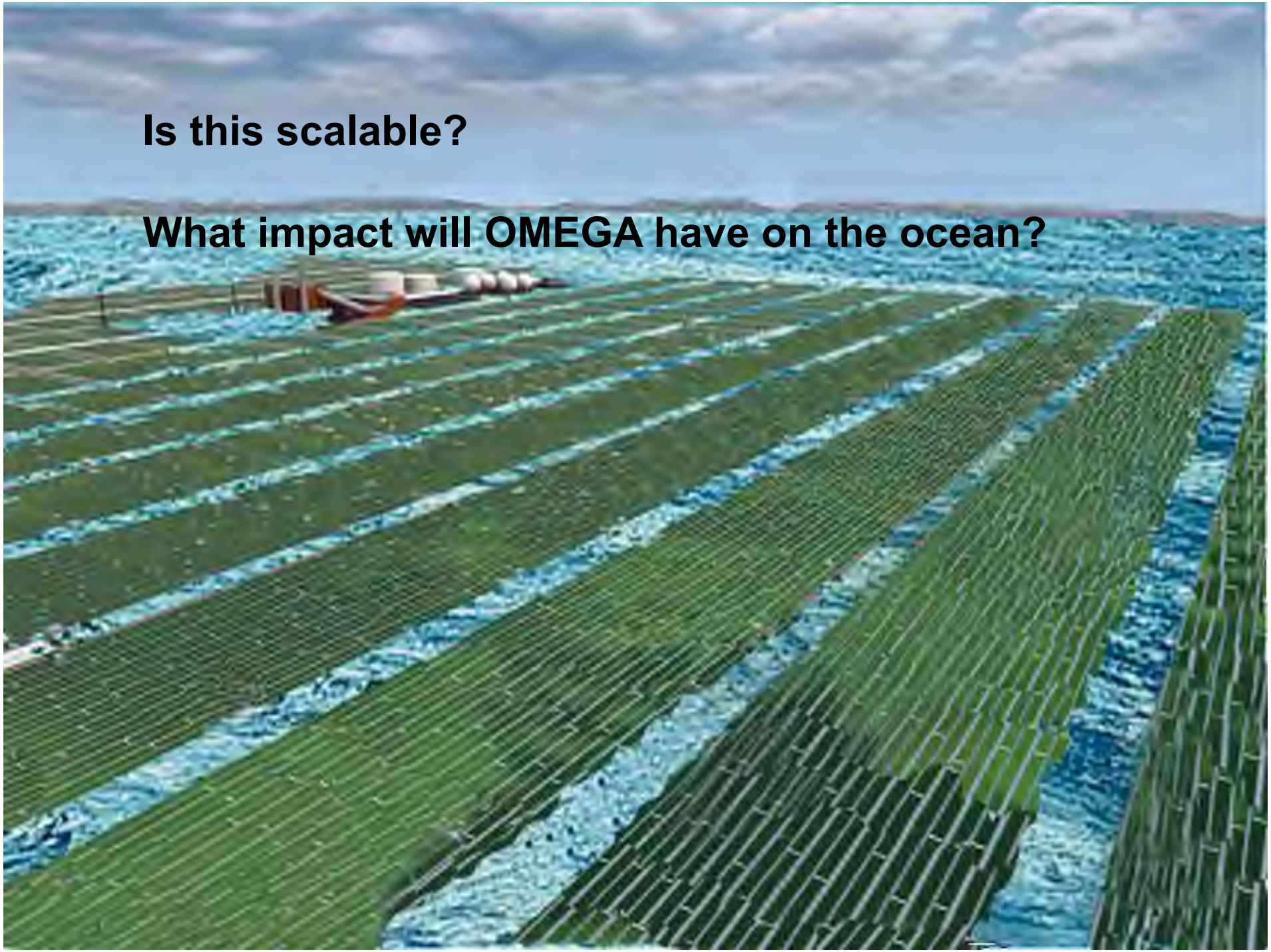



Culture layer
Gas-permeable membrane
CO_2 gas layer


Oregon State University
Conceptual Wave Park
Magnetic Stator
anchored to
sea floor
Electric Coil
secured to
heaving buoy
Permanent Magnet
Linear Generator Buoy
Source: Nicolle Rager Fuller, NSF




To mooring
To boat
Wave-powered pump

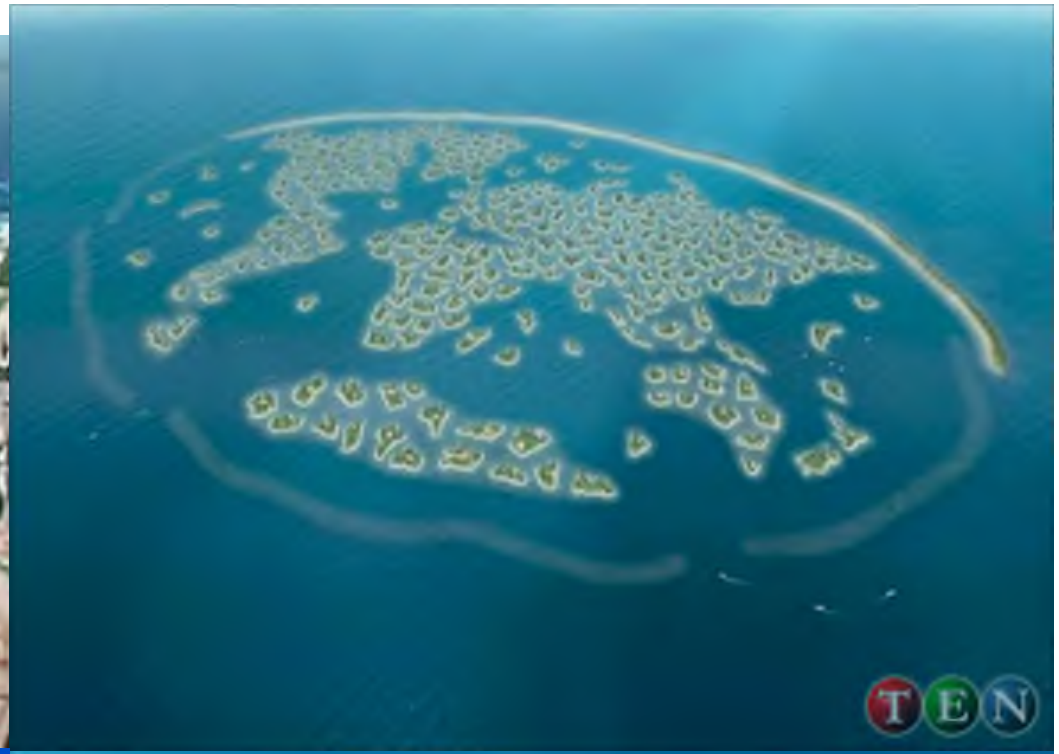

Is this scalable?
What impact will OMEGA have on the ocean?


14 16:04


Jan Parker 2006


How realistic is OMEGA?


Are we up to the engineering challenge?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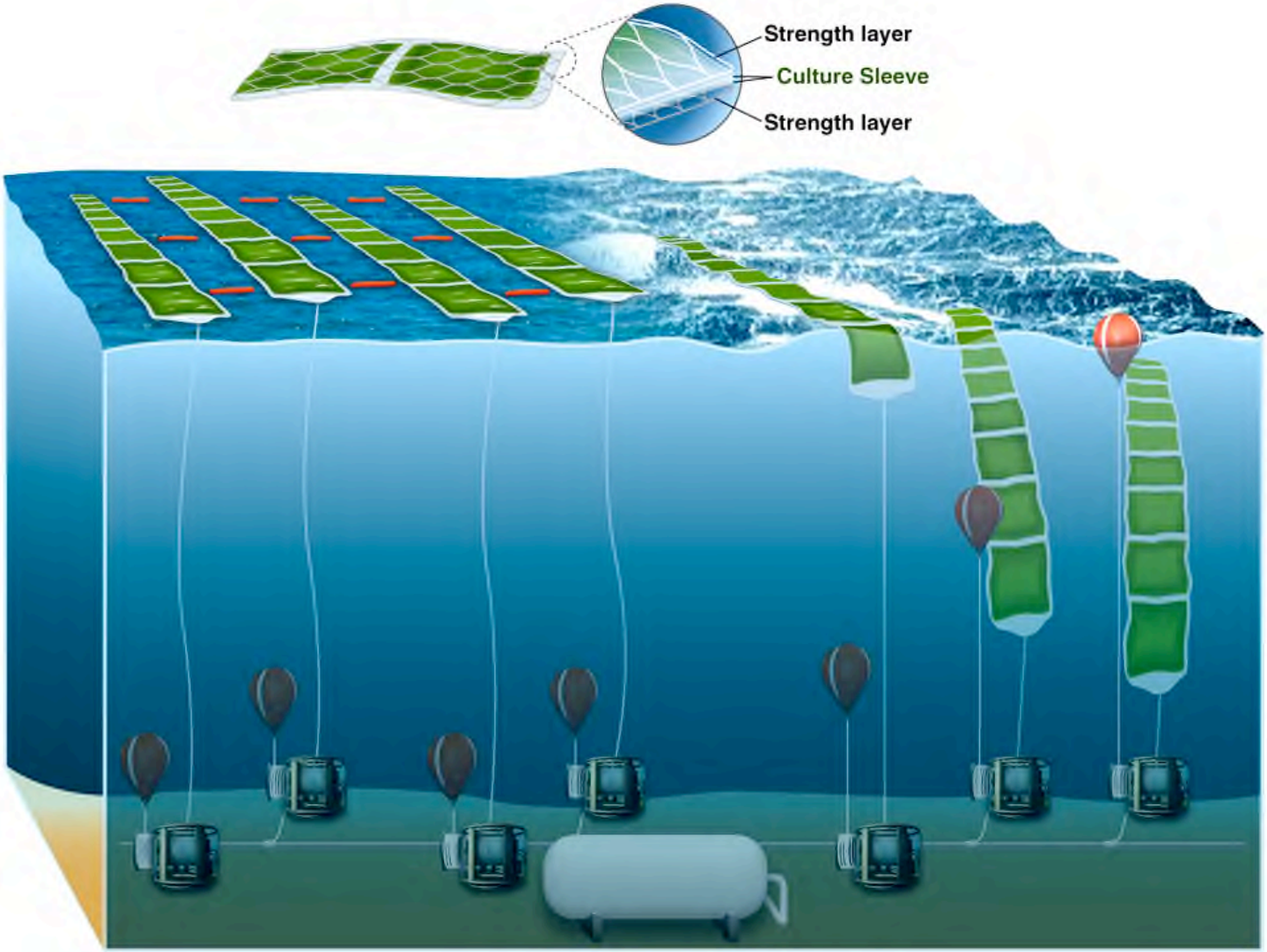
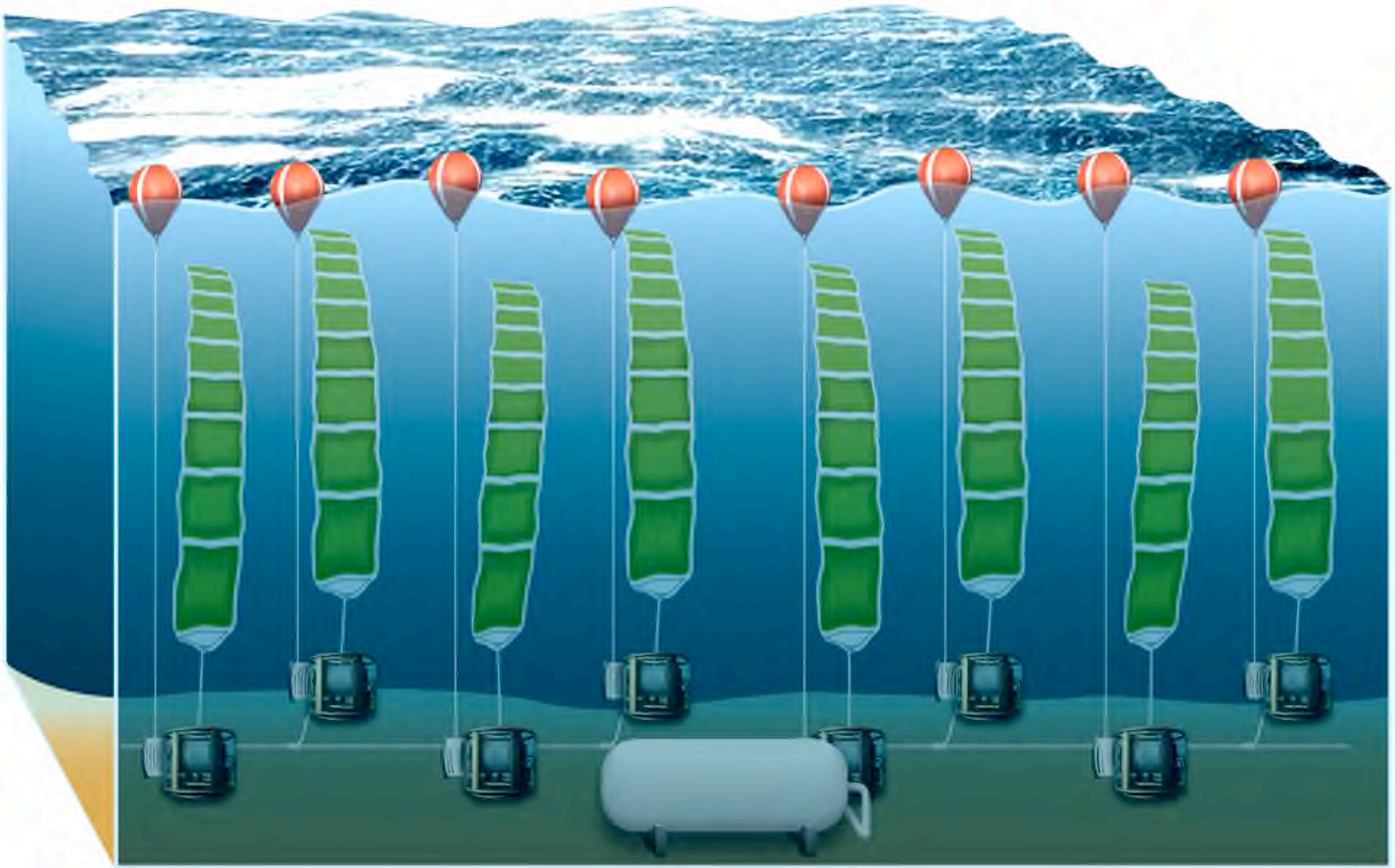
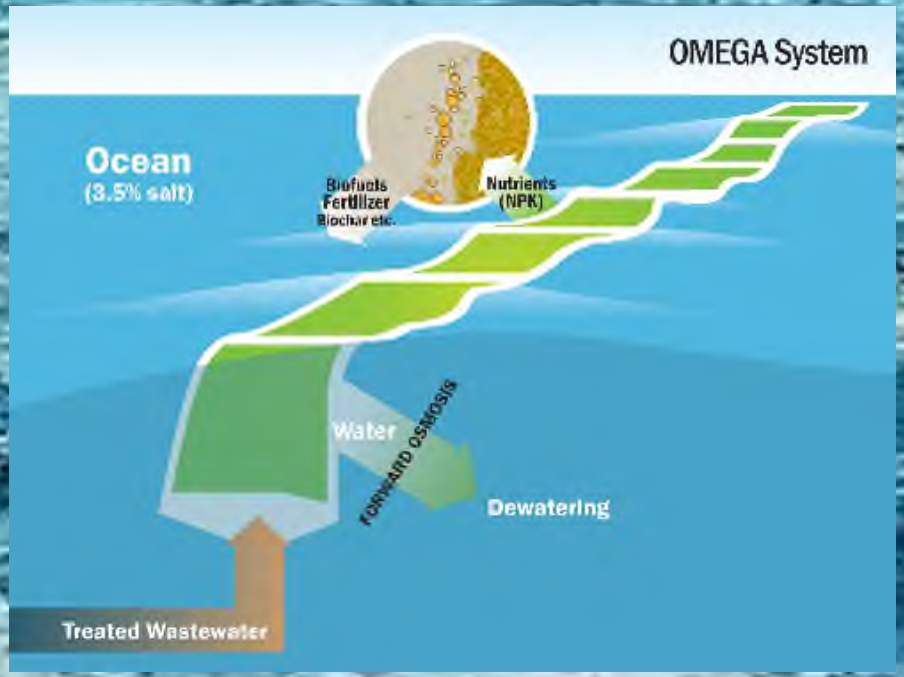

Strength layer
Culture Sleeve
Strength layer




Challenges for OMEGA
•!Biology
•!Engineering
•!Economics
•!Environment

NASA OMEGA

Demonstration Project



Motivations for OMEGA

Does not compete with agriculture

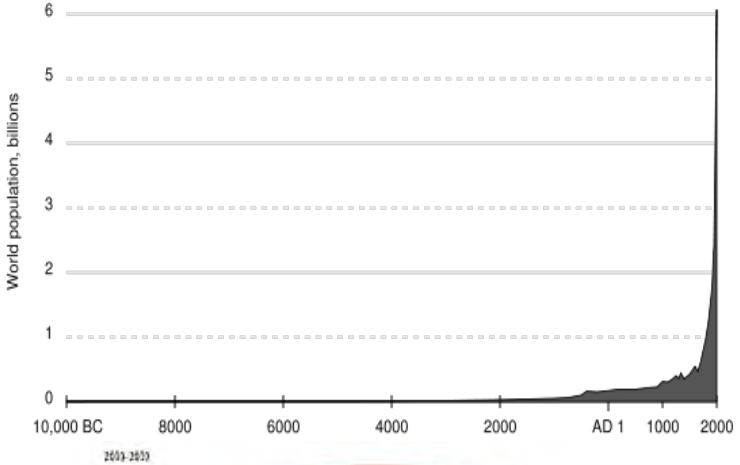
- !Land
- !Freshwater
- !Fertilizer

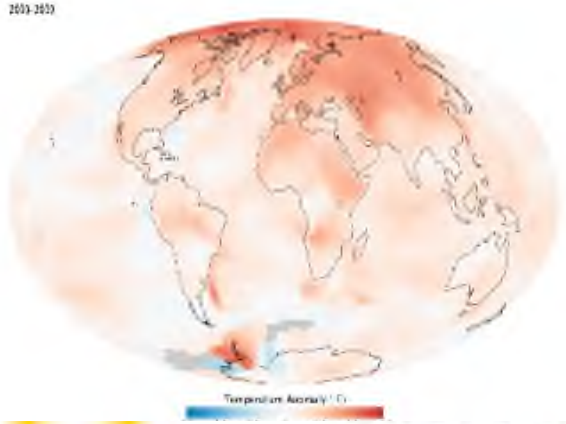
Compatible with climate change

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

Creates an ecology of technology

- !Waste = resource






STATE OF CALIFORNIA
ENERGY COMMISSION


NASA


Ames Research Center


URS


UC SANTA CRUZ


SETI INSTITUTE


SRI


SCHOOL OF MINES
1874
COLORADO


DYNAMAC
CORPORATION


CALIFORNIA


NREL
National Renewable
Energy Laboratory


UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY


SFPUC
WATER
HETCH HETCHY
WATER & POWER
CLEAN WATER


BCI


WESTECH
an employee-owned company


EIMCO
WATERTECHNOLOGIES

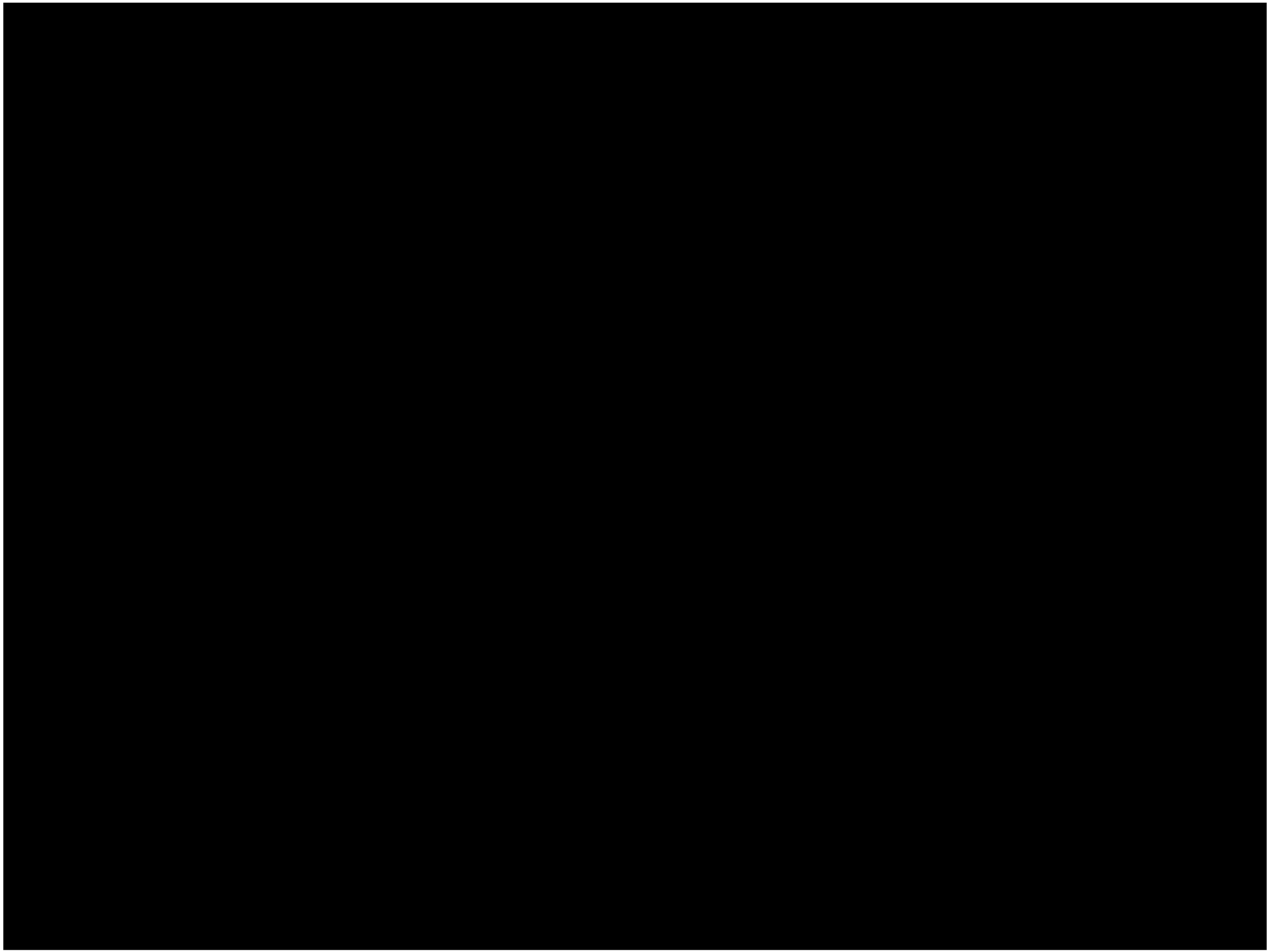

SIEMENS
Water Technologies


SRI
International

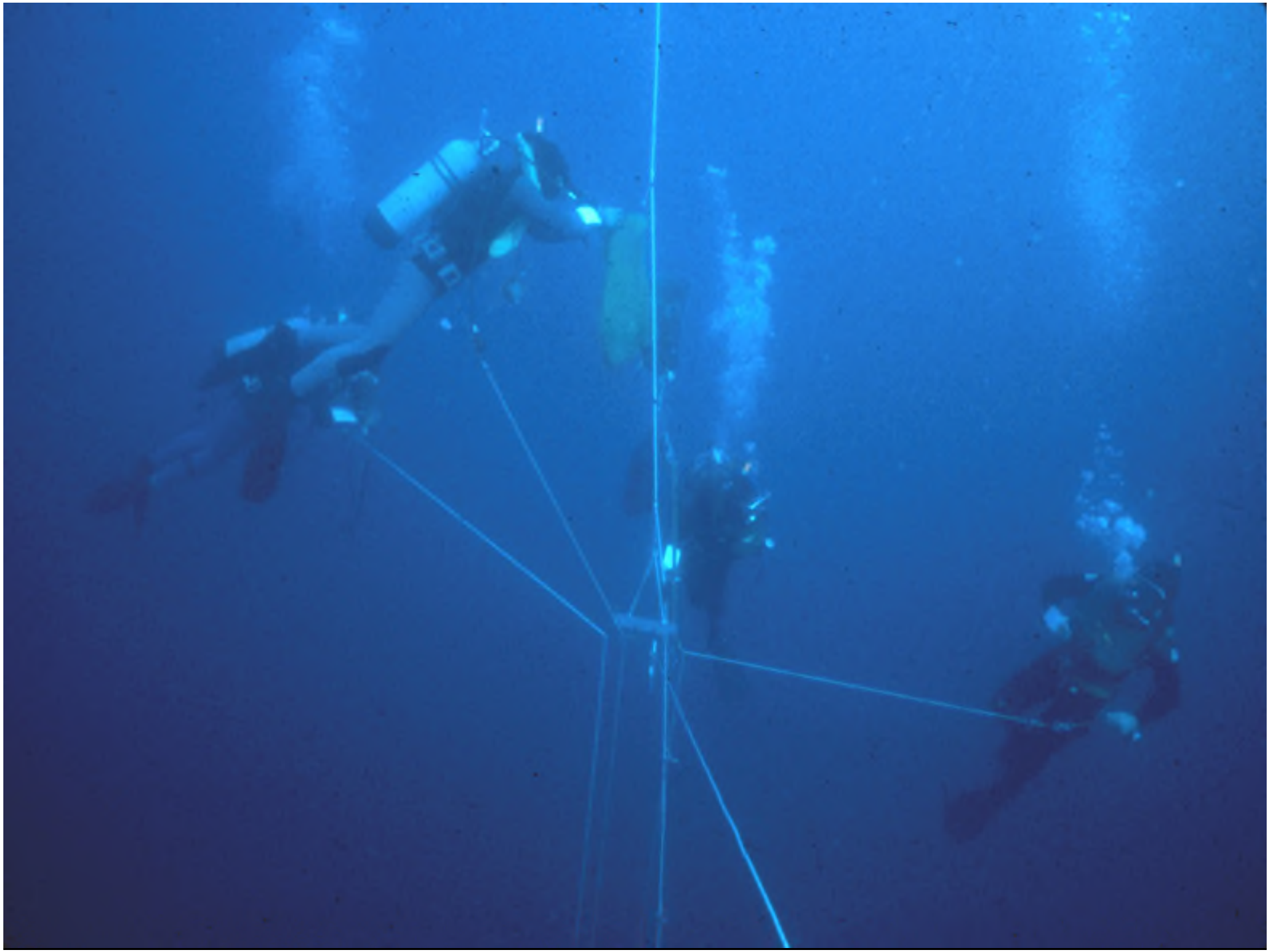

uop
A Honeywell Company

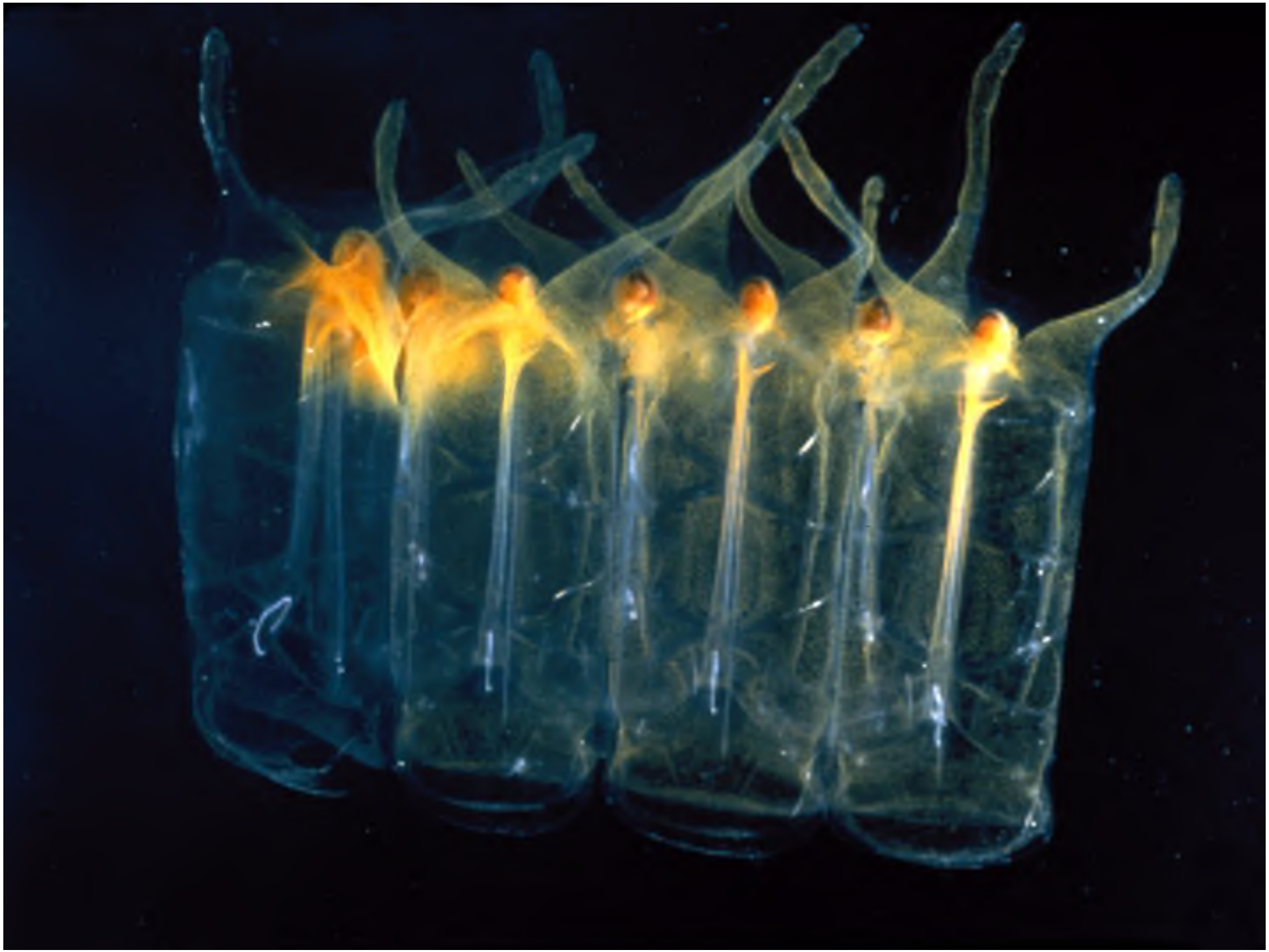
"…what we really want is for things to stay the same, but get better."

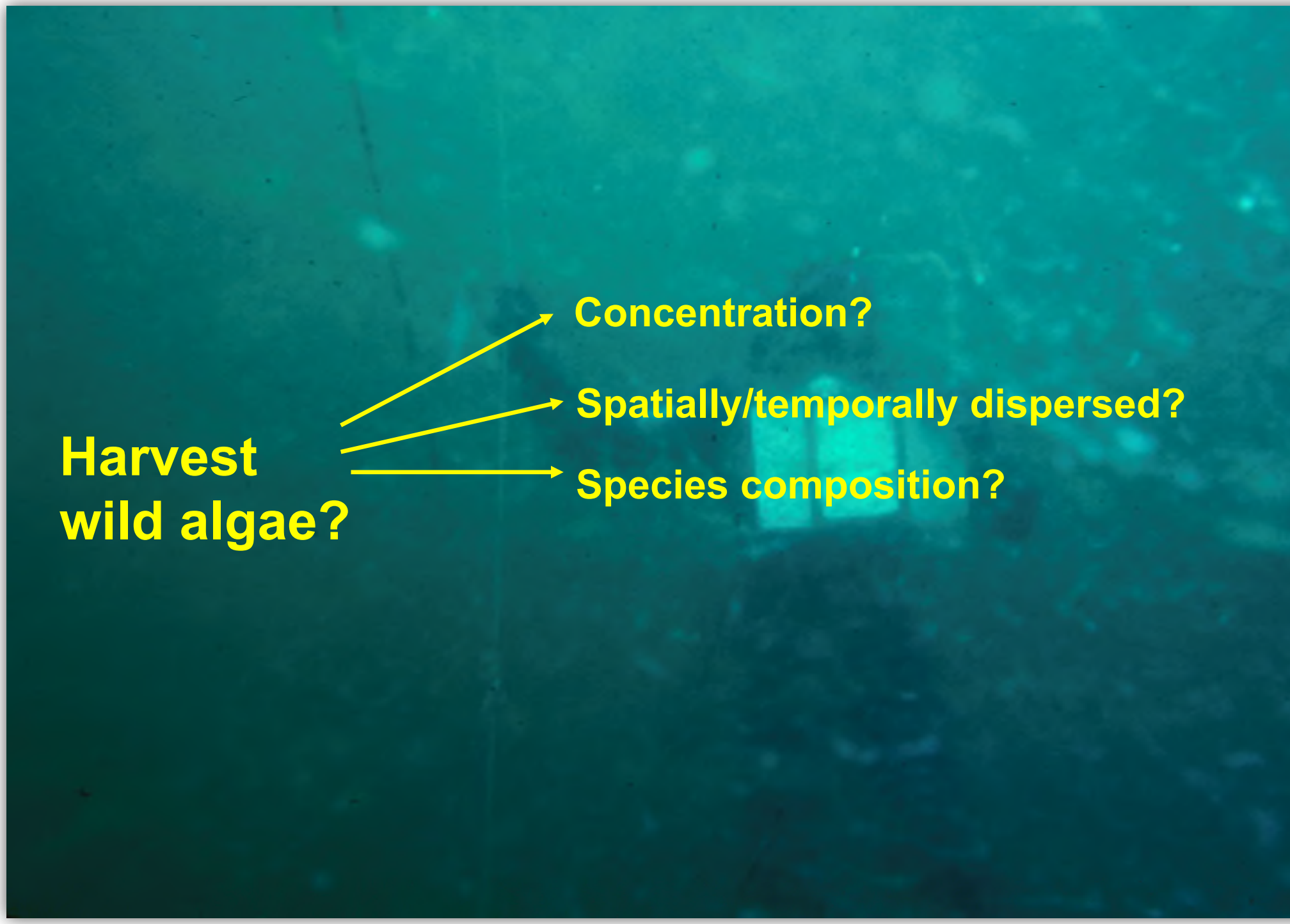
Is the future really in algae?

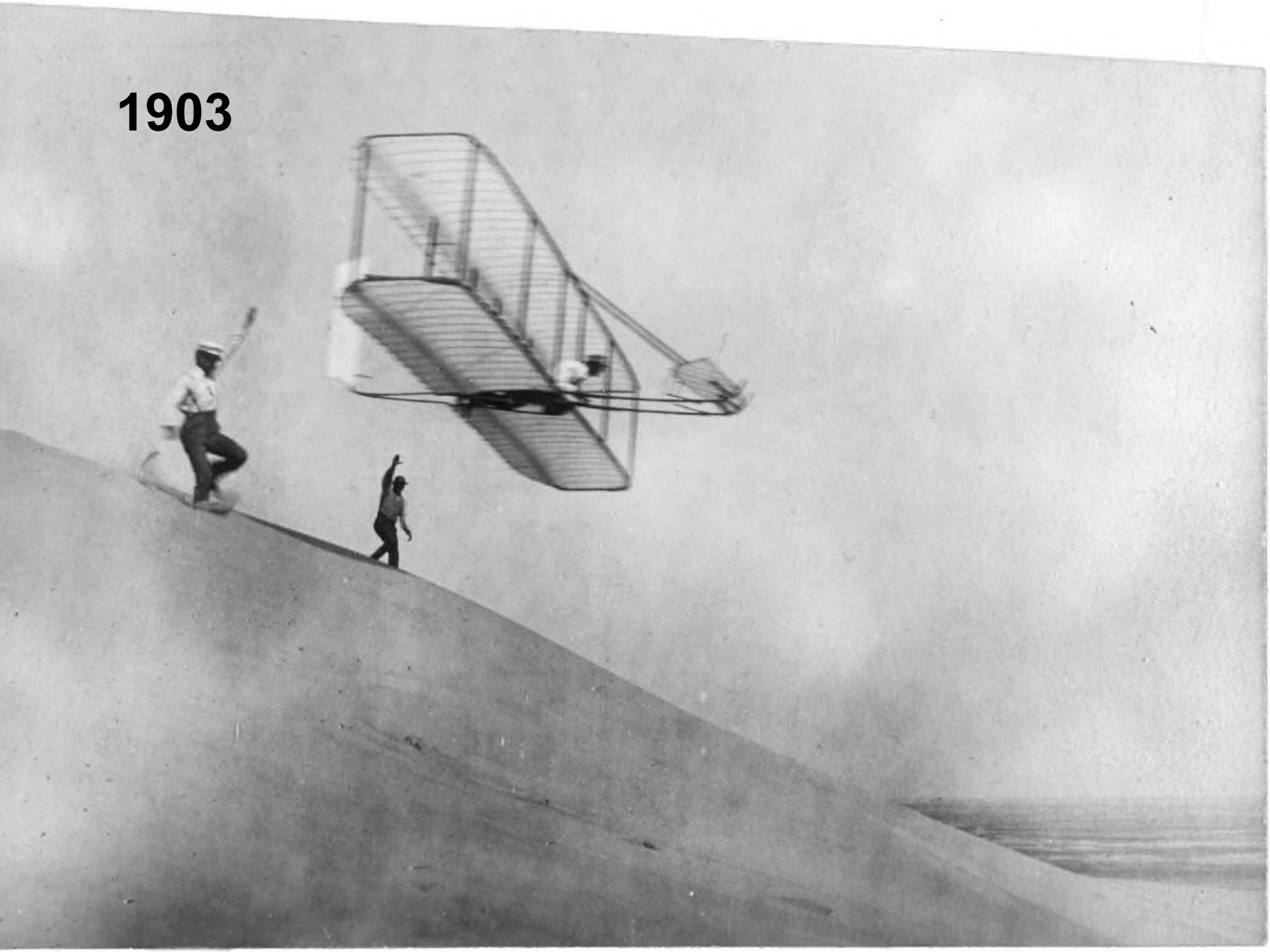



What about collecting wild
algae from the ocean?

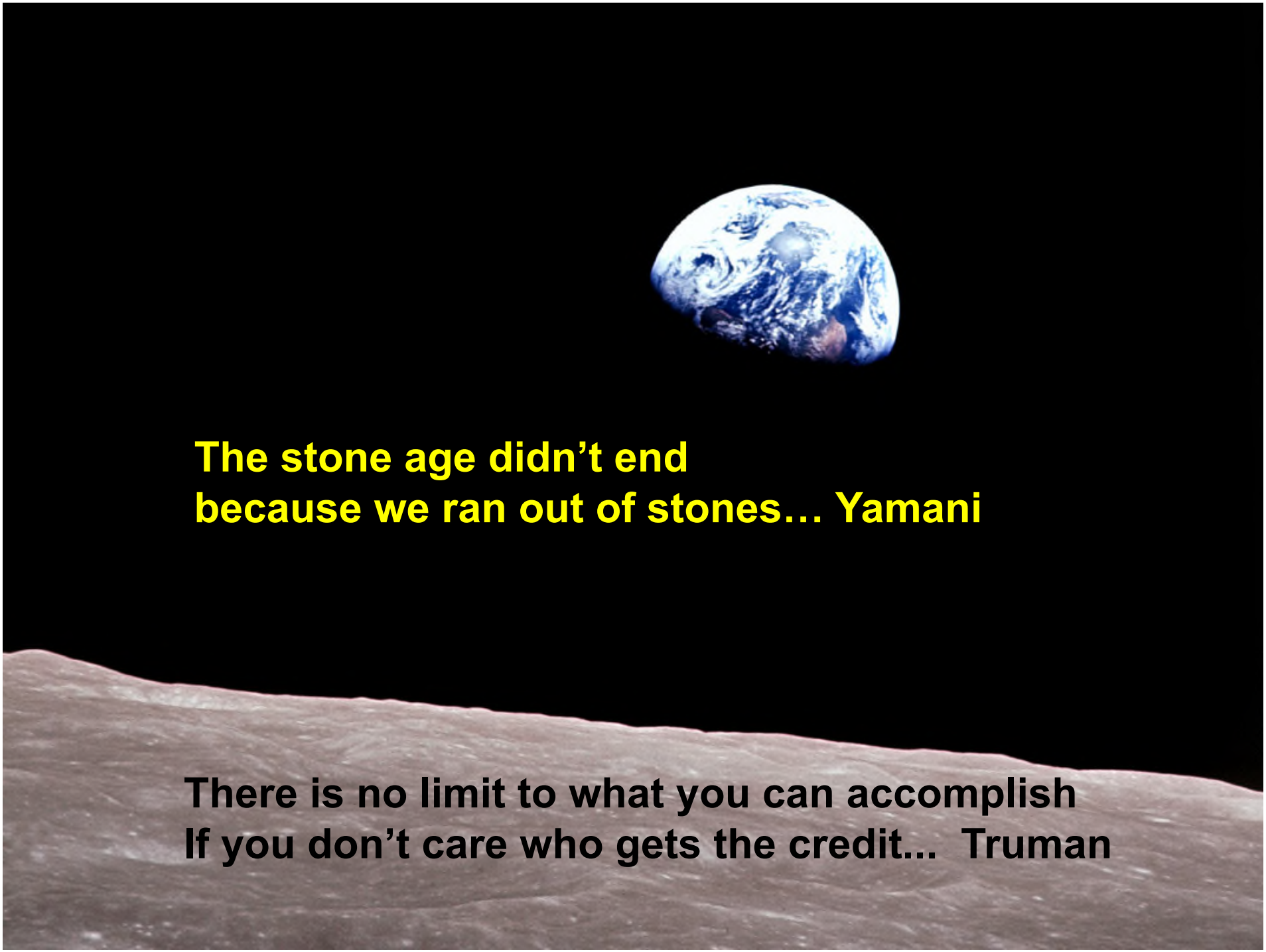





Harvest
wild algae?
Concentration?
Spatially/temporally dispersed?
Species composition?


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