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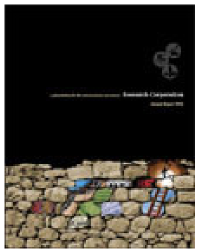
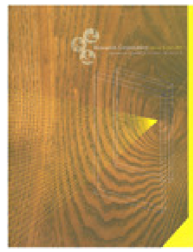
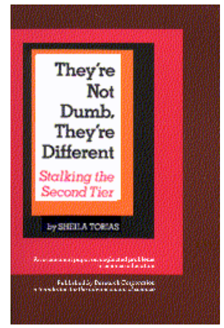
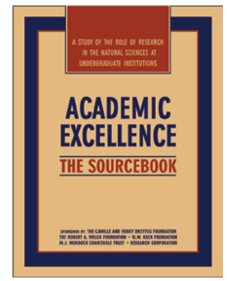
for SCIENCE ADVANCEMENT

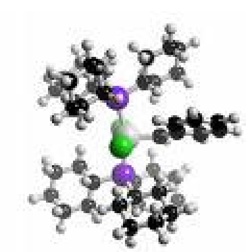
A foundation dedicated to science since 1912.

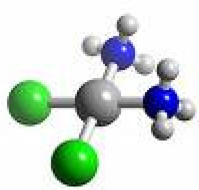


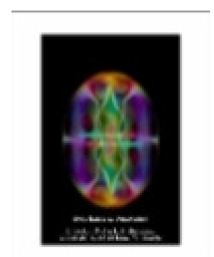


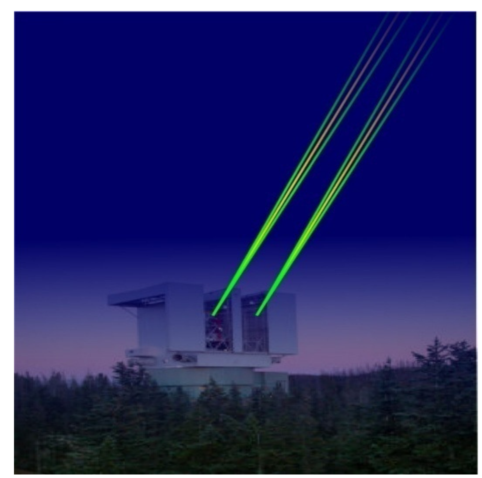












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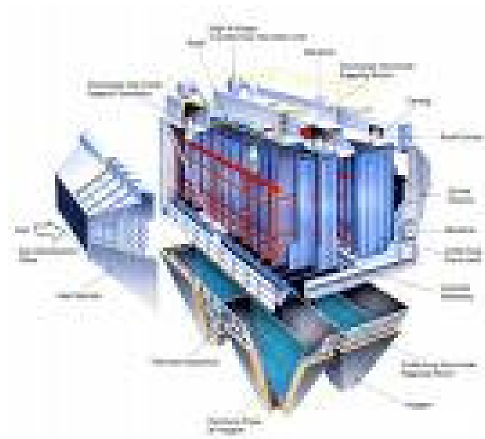
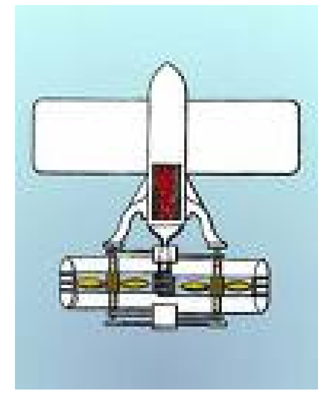
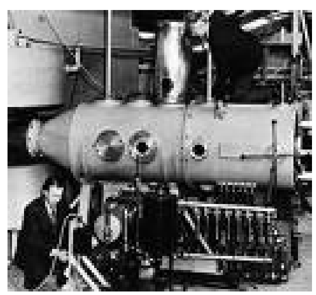


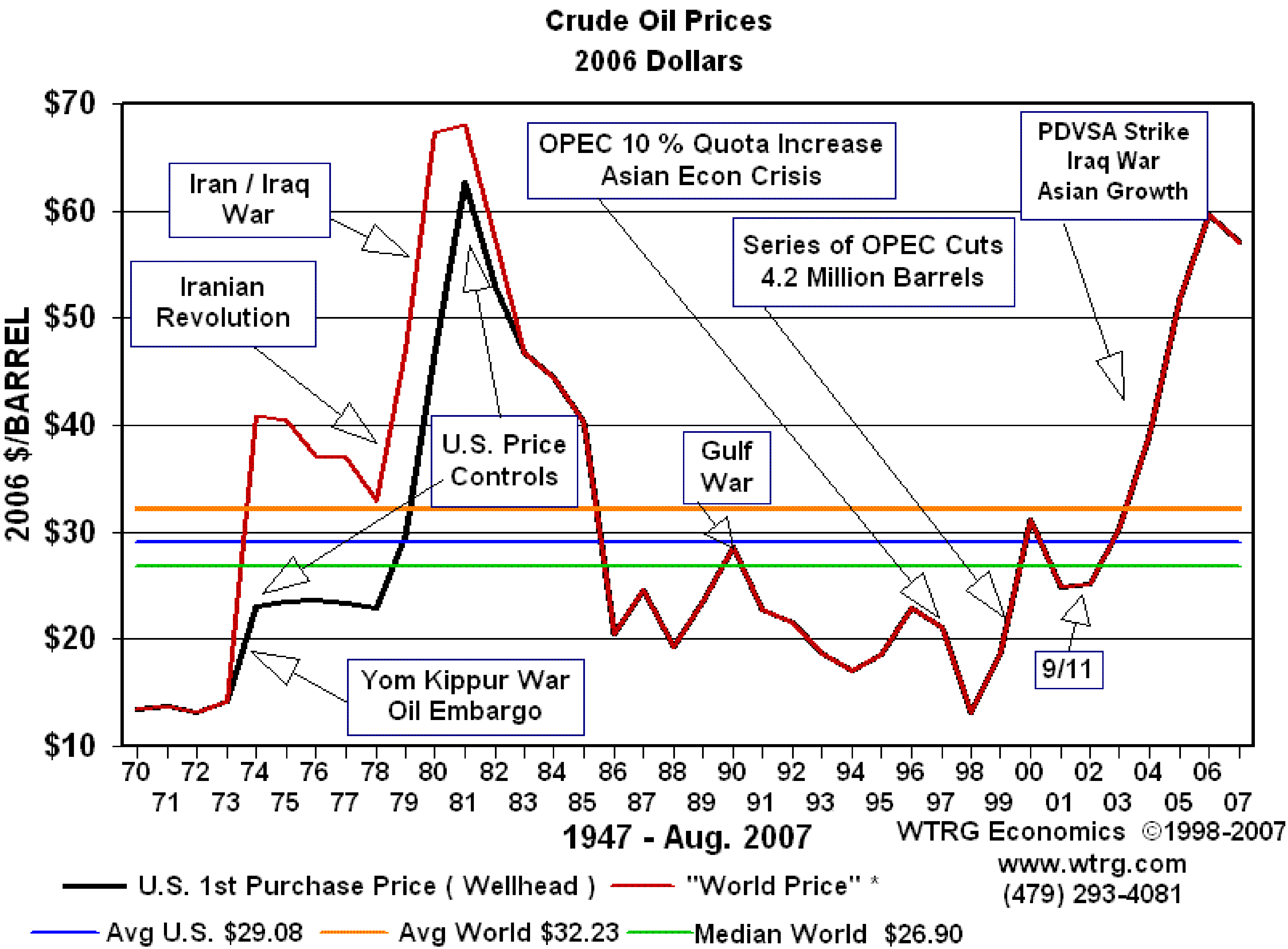




What is Science?

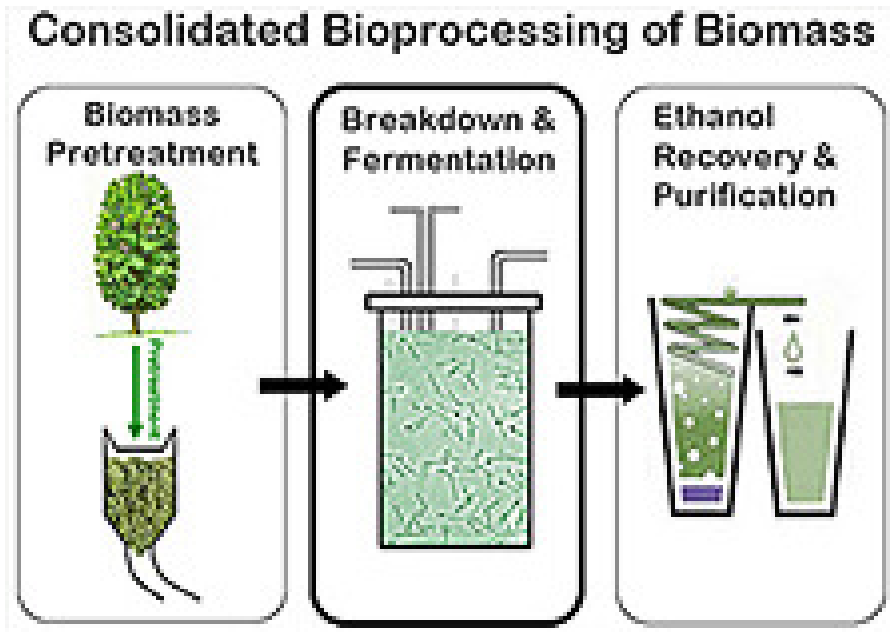
"Science is not a collection of facts, nor is it something that happens in a laboratory. Science happens in the head; it is a flight of imagination beyond the constraints of ordinary perception"

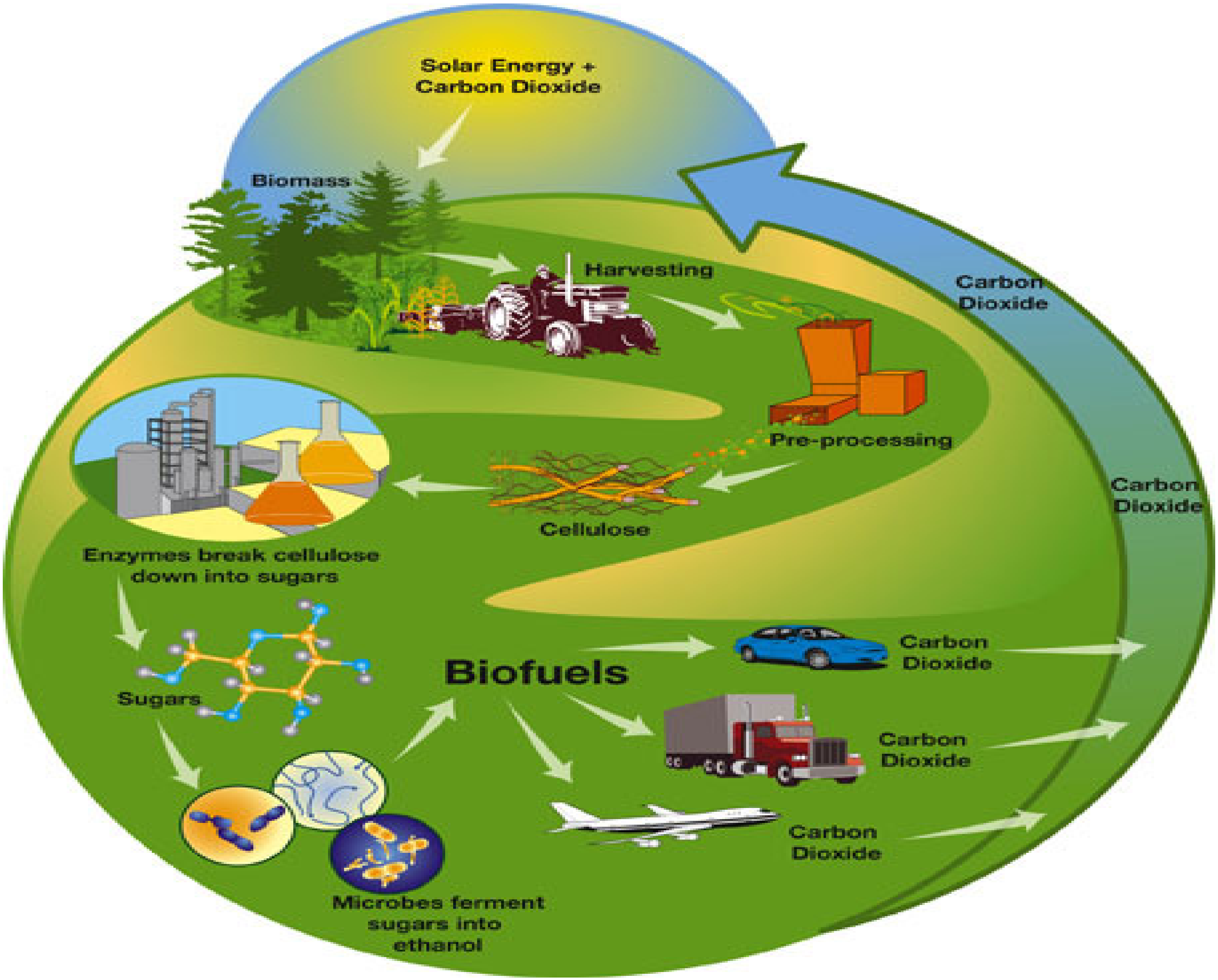

Source: Danish Center for Biofuels



Crude Oil Prices
2006 Dollars
$70
$60
$50
$40
$30
$20
$10
2006 $/BARREL
Iran / Iraq War
Iranian Revolution
U.S. Price Controls
OPEC 10 % Quota Increase
Asian Econ Crisis
Series of OPEC Cuts
4.2 Million Barrels
PDVSA Strike
Iraq War
Asian Growth
Gulf War
9/11
Yom Kippur War
Oil Embargo
70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 00 02 04 06
71 73 75 77 79 81 83 85 87 89 91 93 95 97 99 01 03 05 07
1947 - Aug. 2007
WTRG Economics ©1998-2007
www.wtrg.com
(479) 293-4081
U.S. 1st Purchase Price (Wellhead)
"World Price" *
Avg U.S. $29.08
Avg World $32.23
Median World $26.90

Biofuels – short version

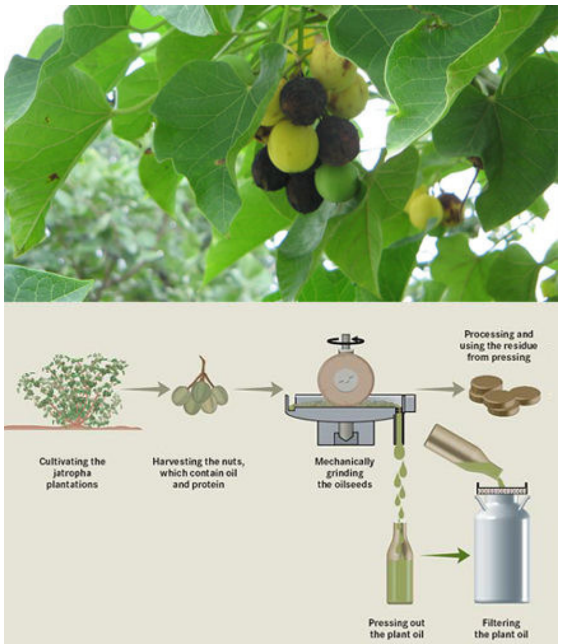


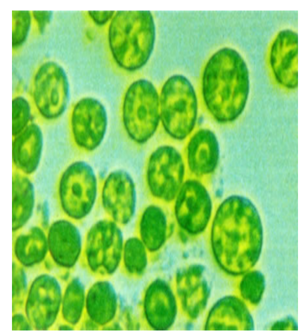


Solar Energy +
Carbon Dioxide
Biomass
Harvesting
Carbon
Dioxide
Pre-processing
Carbon
Dioxide
Cellulose
Enzymes break cellulose
down into sugars
Sugars
Biofuels
Carbon
Dioxide
Carbon
Dioxide
Carbon
Dioxide
Microbes ferment
sugars into
ethanol

Various Plants Under Study

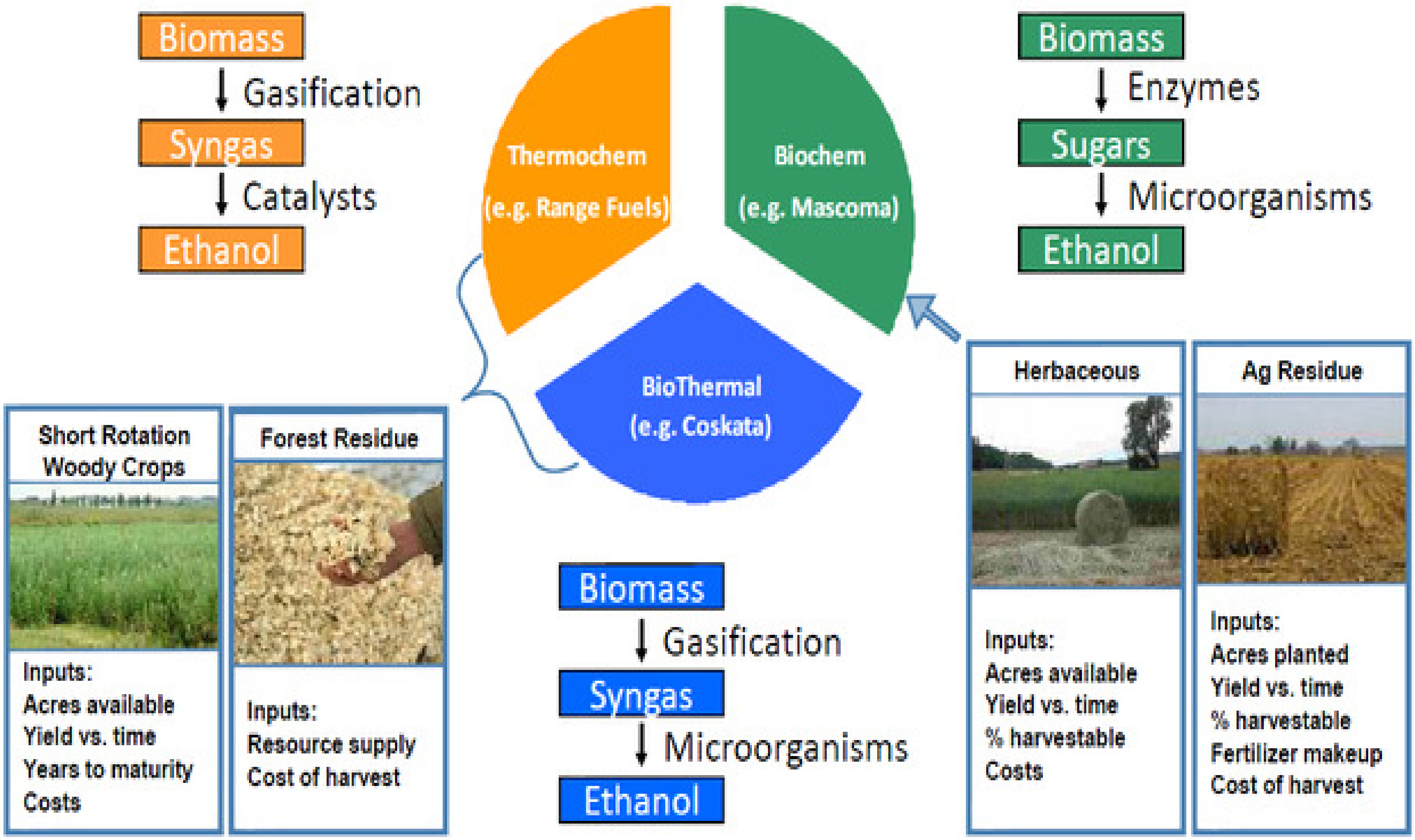
Jatropha, Agavae, Maize, Salcanoria, algae, many others – even wood chips



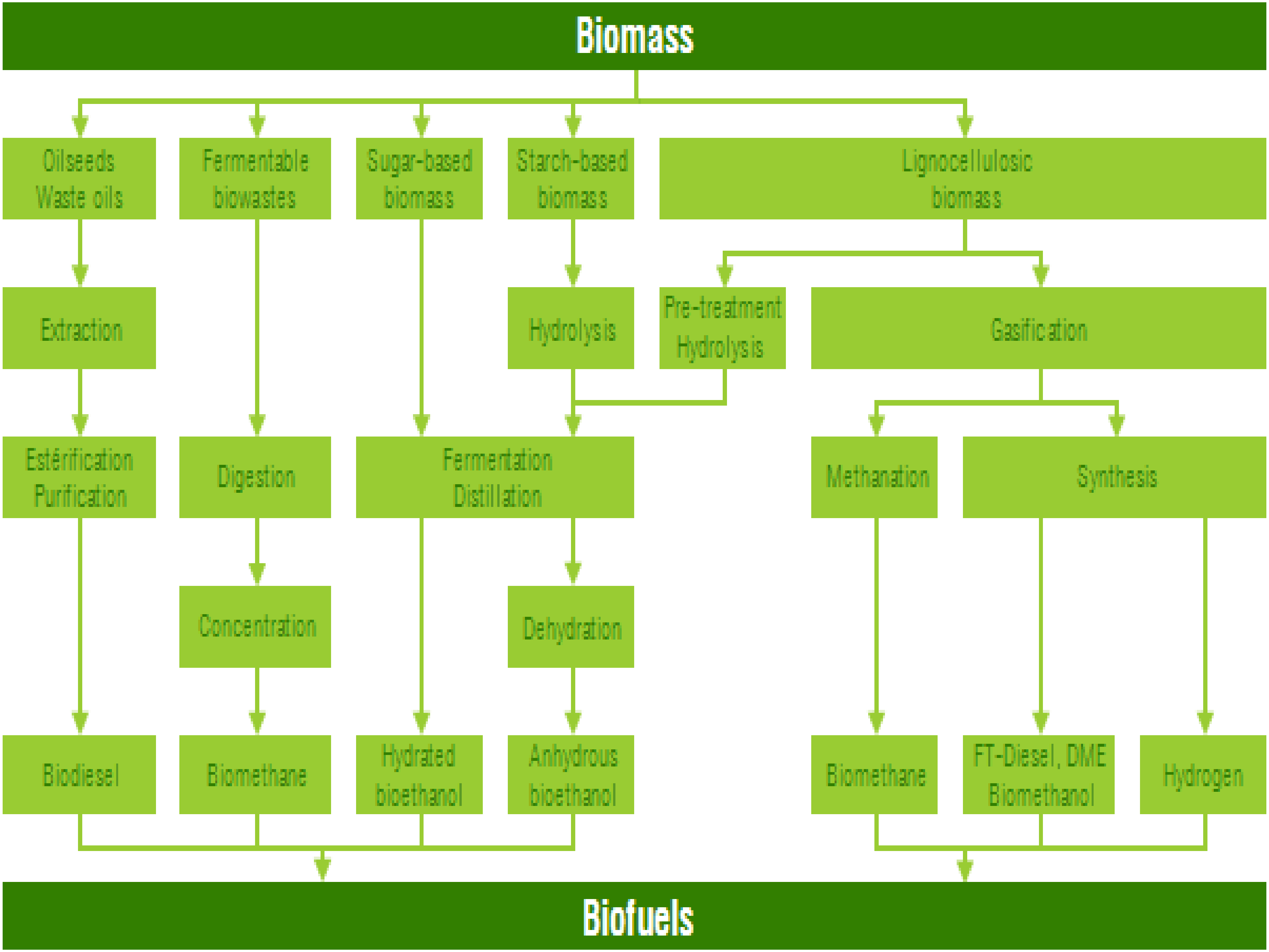


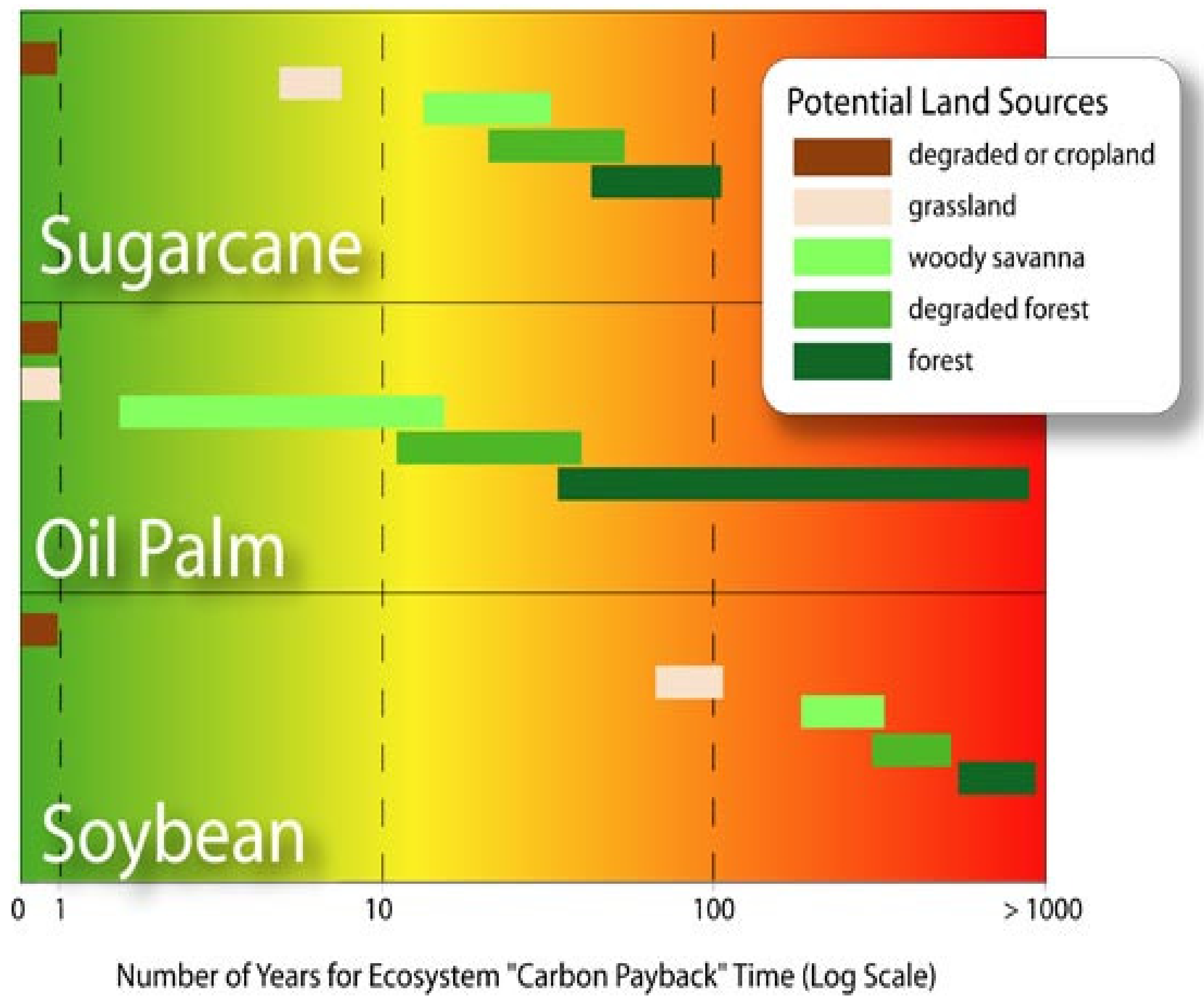
Conversion technologies are linked with specific feedstocks

For each new plant constructed, the Biofuels Deployment Model (BDM) selects a feedstock/conversion pair resulting in lowest cost of ethanol

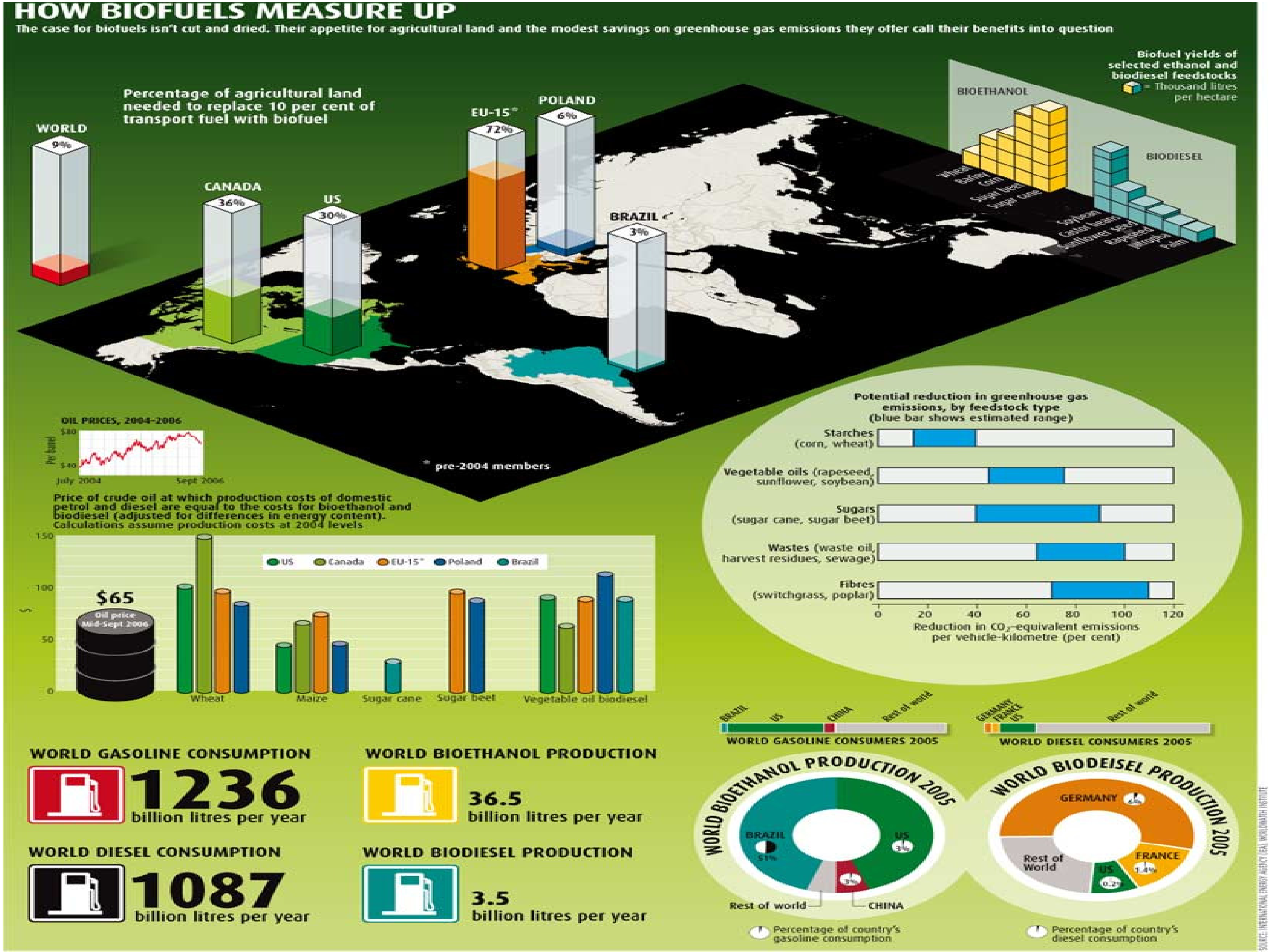


Above linkages are only representative – other combinations possible


Biomass
Oilseeds
Waste oils
Fermentable
biowastes
Sugar-based
biomass
Starch-based
biomass
Lignocellulosic
biomass
Extraction
Hydrolysis
Pre-treatment
Hydrolysis
Gasification
Estérification
Purification
Digestion
Fermentation
Distillation
Methanation
Synthesis
Concentration
Dehydration
Biodiesel
Biomethane
Hydrated
bioethanol
Anhydrous
bioethanol
Biomethane
FT-Diesel, DME
Biomethanol
Hydrogen
Biofuels



Potential Land Sources
degraded or cropland
grassland
woody savanna
degraded forest
forest
Sugarcane
Oil Palm
Soybean
0
1
10
100
> 1000
Number of Years for Ecosystem "Carbon Payback" Time (Log Scale)



HOW BIOFUELS MEASURE UP
The case for biofuels isn't cut and dried. Their appetite for agricultural land and the modest savings on greenhouse gas emissions they offer call their benefits into question
Percentage of agricultural land needed to replace 10 per cent of transport fuel with biofuel
WORLD 9%
CANADA 36%
US 30%
EU-15* 72%
POLAND 6%
BRAZIL 3%
* pre-2004 members
Biofuel yields of selected ethanol and biodiesel feedstocks
= Thousand litres per hectare
BIOETHANOL
Wheat
Barley
Corn
Sugar beet
Sugar cane
BIODIESEL
Soybean
Castor bean
Sunflower seed
Rapeseed
Jatropha
Palm
OIL PRICES, 2004-2006
$80
$40
Per barrel
July 2004
Sept 2006
Price of crude oil at which production costs of domestic petrol and diesel are equal to the costs for bioethanol and biodiesel (adjusted for differences in energy content). Calculations assume production costs at 2004 levels
150
100
50
0
$
US
Canada
EU-15*
Poland
Brazil
$65
Oil price Mid-Sept 2006
Wheat
Maize
Sugar cane
Sugar beet
Vegetable oil biodiesel
Potential reduction in greenhouse gas emissions, by feedstock type (blue bar shows estimated range)
Starches (corn, wheat)
Vegetable oils (rapeseed, sunflower, soybean)
Sugars (sugar cane, sugar beet)
Wastes (waste oil, harvest residues, sewage)
Fibres (switchgrass, poplar)
0
20
40
60
80
100
120
Reduction in CO_2-equivalent emissions per vehicle-kilometre (per cent)
WORLD GASOLINE CONSUMPTION
1236
billion litres per year
WORLD BIOETHANOL PRODUCTION
36.5
billion litres per year
WORLD DIESEL CONSUMPTION
1087
billion litres per year
WORLD BIODIESEL PRODUCTION
3.5
billion litres per year
BRAZIL
US
CHINA
Rest of world
WORLD GASOLINE CONSUMERS 2005
GERMANY
FRANCE
US
Rest of world
WORLD DIESEL CONSUMERS 2005
WORLD BIOETHANOL PRODUCTION 2005
BRAZIL
51%
US
3%
3%
Rest of world
CHINA
Percentage of country's gasoline consumption
WORLD BIODEISEL PRODUCTION 2005
GERMANY
6%
FRANCE
1.4%
US
0.2%
Rest of World
Percentage of country's diesel consumption
SOURCE: INTERNATIONAL ENERGY AGENCY (IEA), WORLDWATCH INSTITUTE

HOW GREEN ARE BIOFUELS?

Biofuels are getting a bad rap as stories of rising food prices and shortages fill the news. But the environmental, energy and land use impacts of the crops used to make the fuels vary dramatically. Current fuel sources – corn, soybeans and canola – are more harmful than alternatives that are under development.

FUEL SOURCES

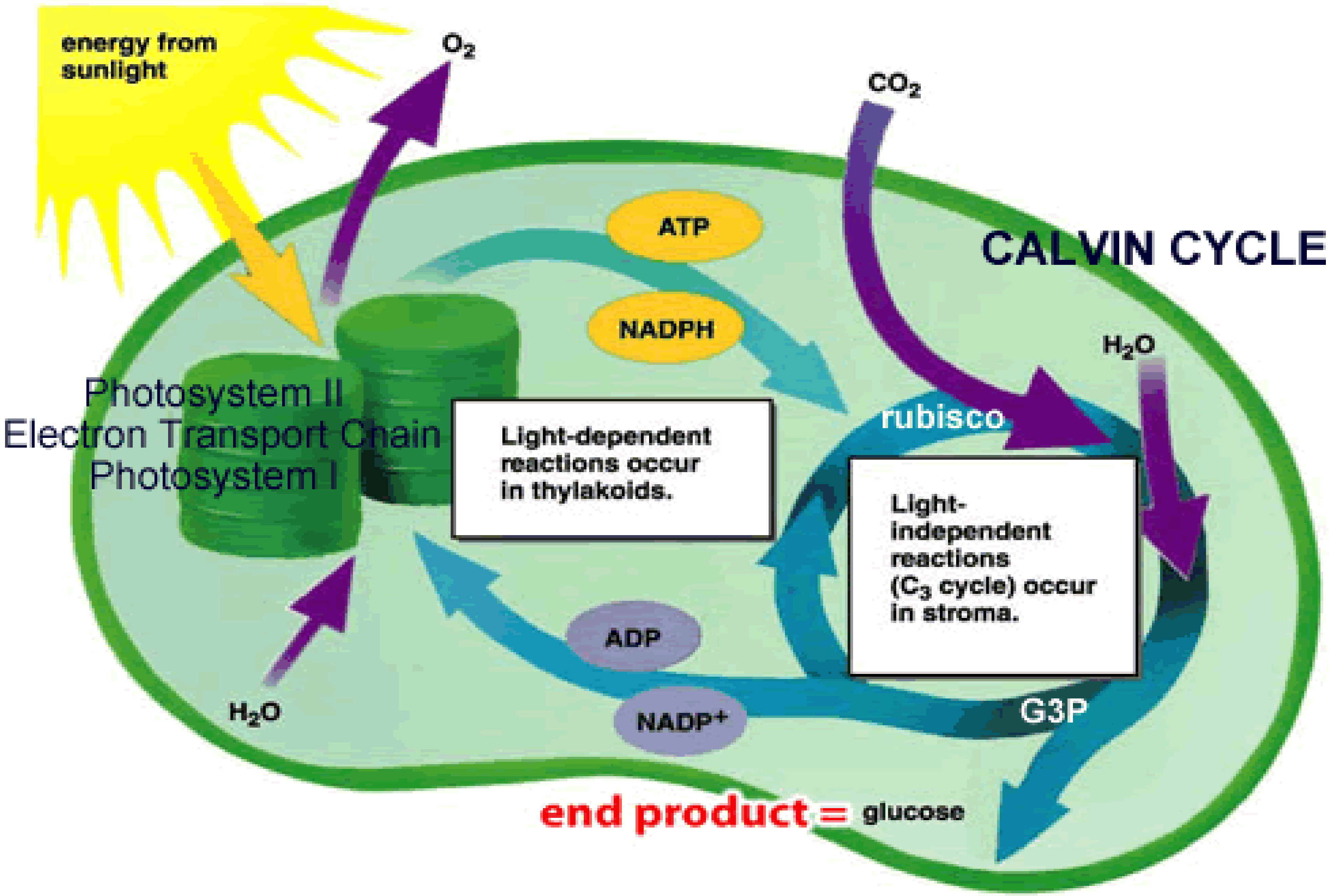
CROP	USED TO PRODUCE	GREENHOUSE GAS EMISSIONS* Kilograms of carbon dioxide created per mega joule of energy produced	USE OF RESOURCES DURING GROWING, HARVESTING AND REFINING OF FUEL: WATER	FERTILIZER	PESTICIDE	ENERGY	PERCENT OF EXISTING U.S. CROP LAND NEEDED TO PRODUCE ENOUGH FUEL TO MEET HALF OF U.S. DEMAND	PROS AND CONS
Corn	Ethanol	81-85	high	high	high	high	157%-262%	Technology ready and relatively cheap, reduces food supply
Sugar cane	Ethanol	4-12	high	high	med	med	46-57	Technology ready, limited as to where will grow
Switch grass	Ethanol	-24	med-low	low	low	low	60-108	Won't compete with food crops, technology not ready
Wood residue	Ethanol, biodiesel	N/A	med	low	low	low	150-250	Uses timber waste and other debris, technology not fully ready
Soybeans	Biodiesel	49	high	low-med	med	med-low	180-240	Technology ready, reduces food supply
Rapeseed, canola	Biodiesel	37	high	med	med	med-low	30	Technology ready, reduces food supply
Algae	Biodiesel	-183	med	low	low	high	1-2	Potential for huge production levels, technology not ready

* Emissions produced during the growing, harvesting, refining and burning of fuel. Gasoline is 94, diesel is 83.

Source: Martha Groom, University of Washington; Elizabeth Gray, The Nature Conservancy; Patricia Townsend, University of Washington; as published in Conservation Biology

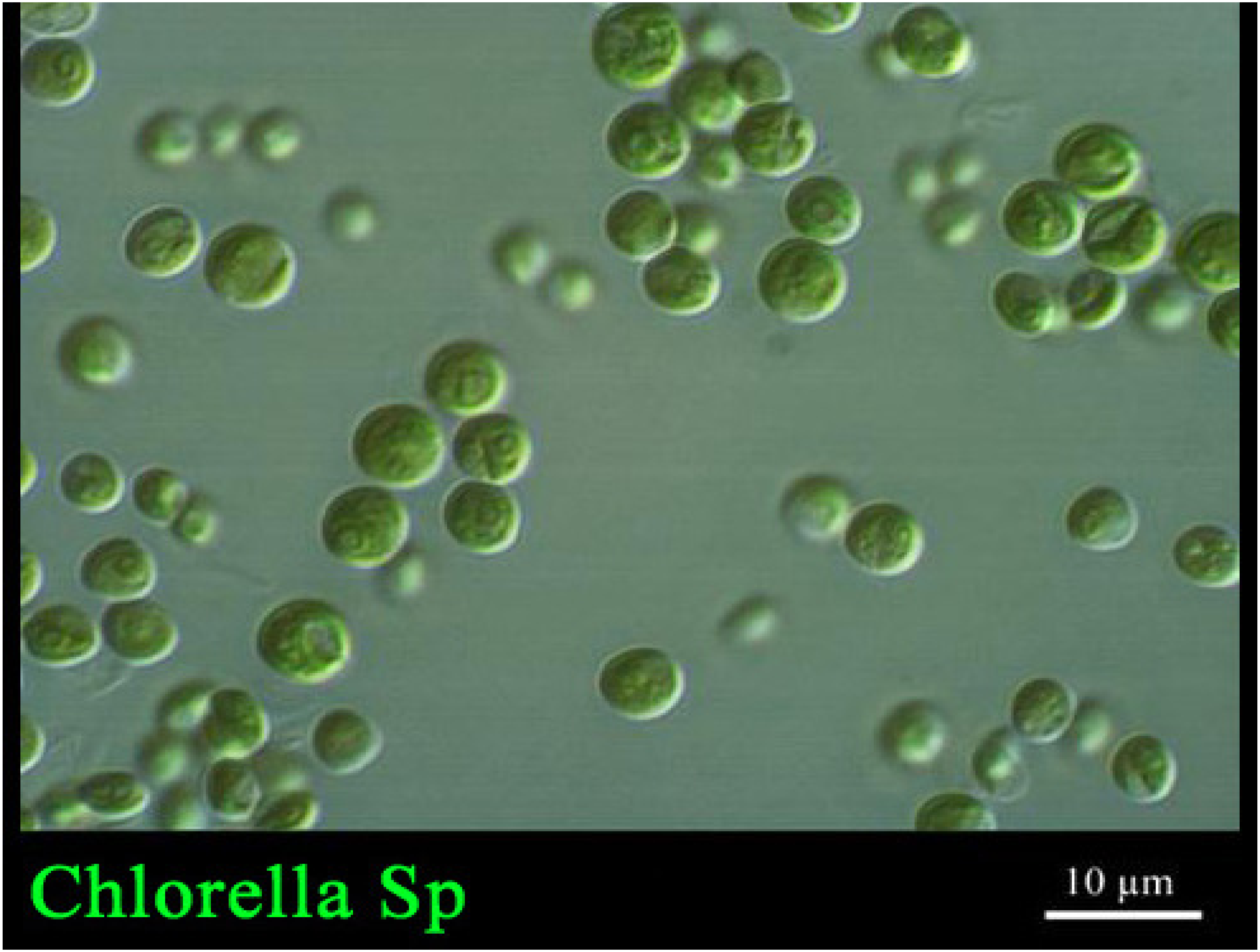
SEATTLE P-I

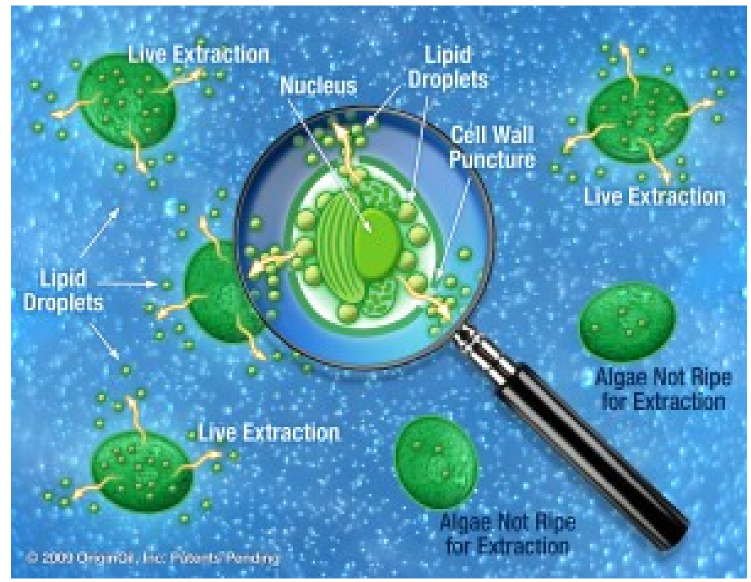
Photosythesis



Dr. Richard Sayer

DONALD DANFORTH
PLANT SCIENCE CENTER


Chlorella Sp
10 µm


Live Extraction
Nucleus
Lipid
Droplets
Cell Wall
Puncture
Live Extraction
Lipid
Droplets
Algae Not Ripe
for Extraction
Live Extraction
Algae Not Ripe
for Extraction
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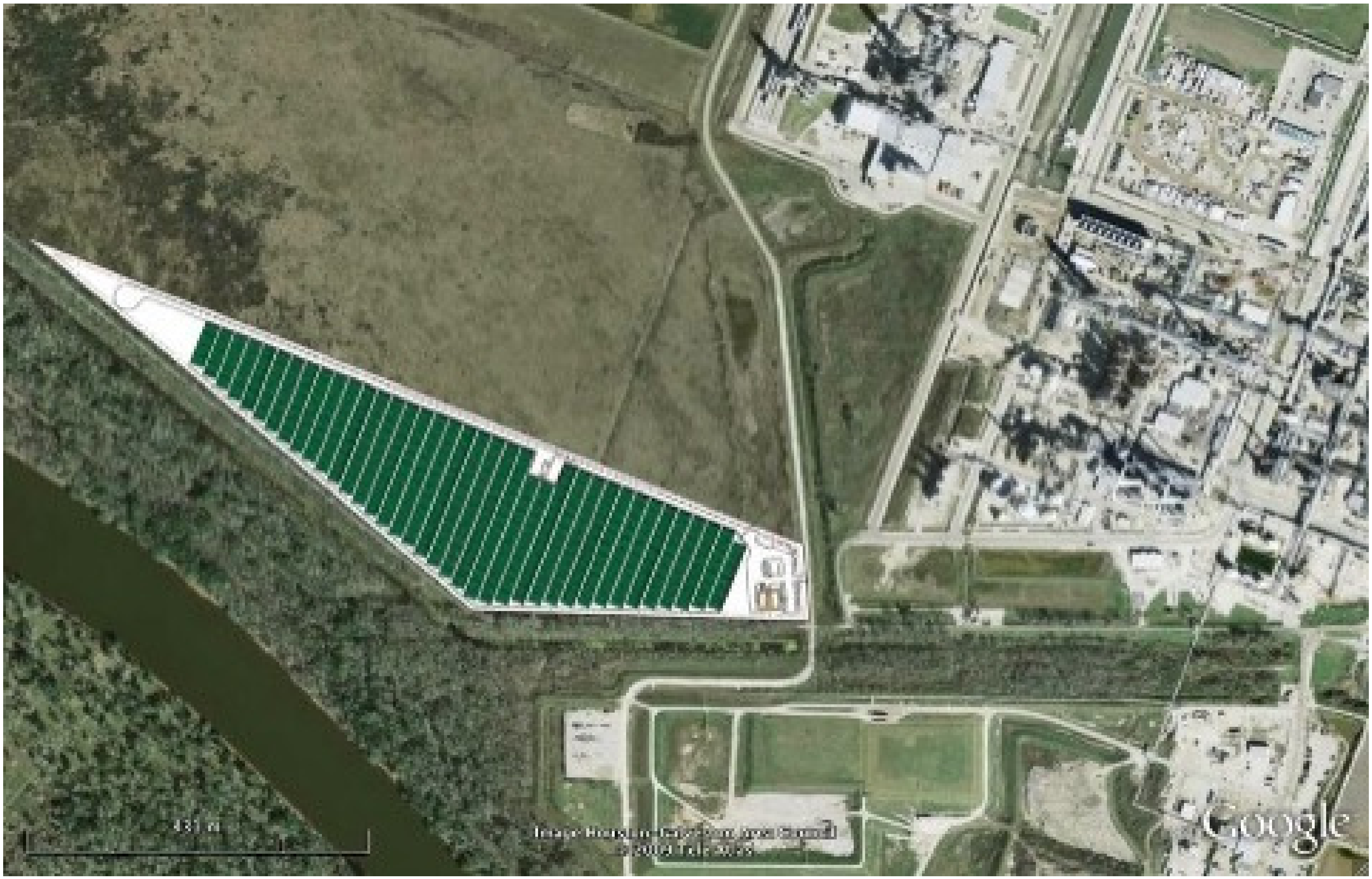
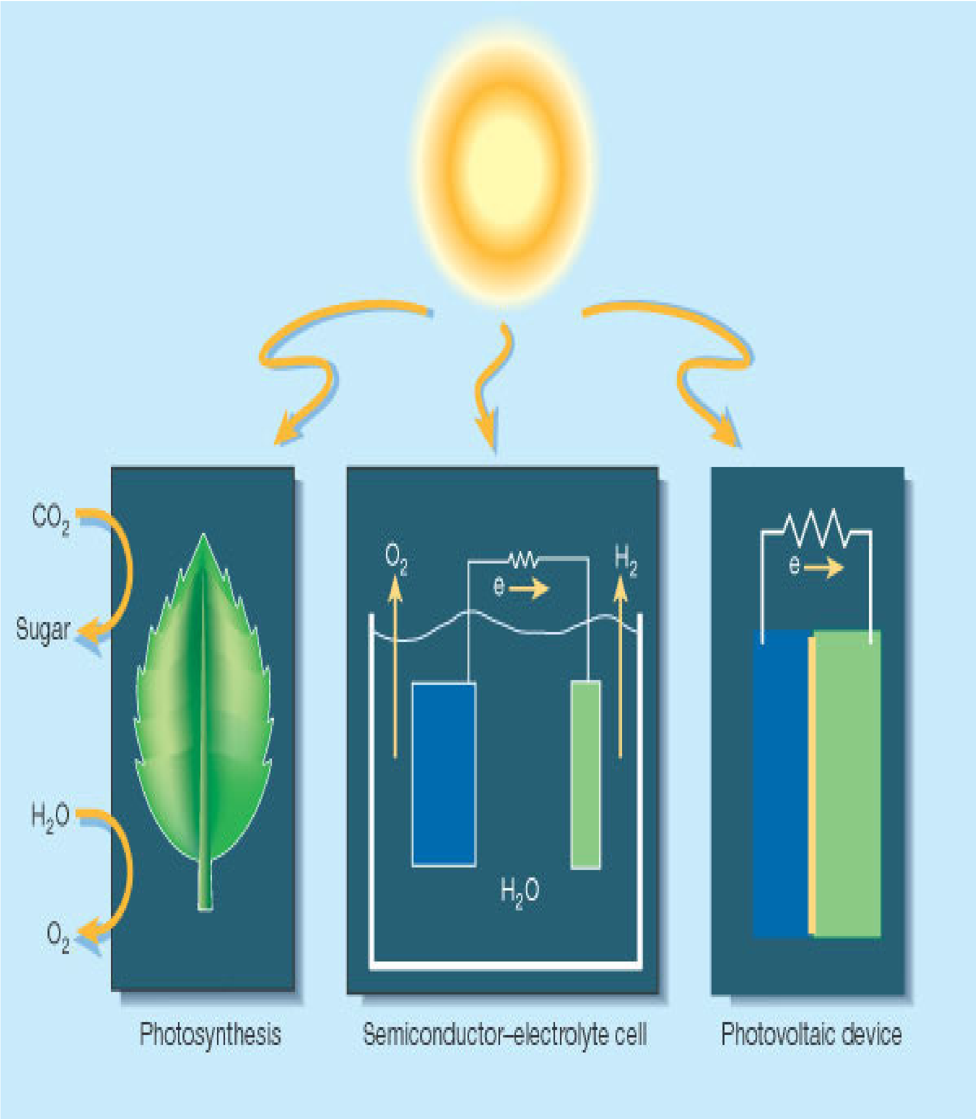
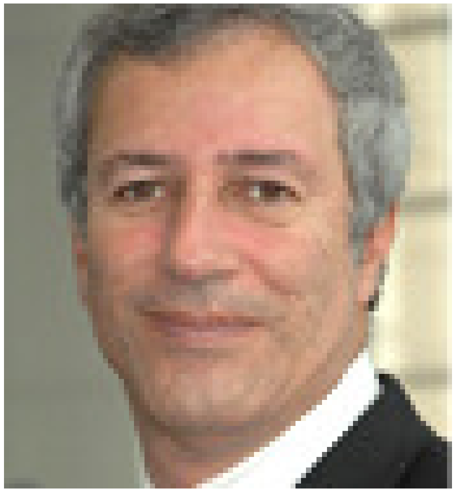
Algae Ethanol at Pilot Plant in Texas

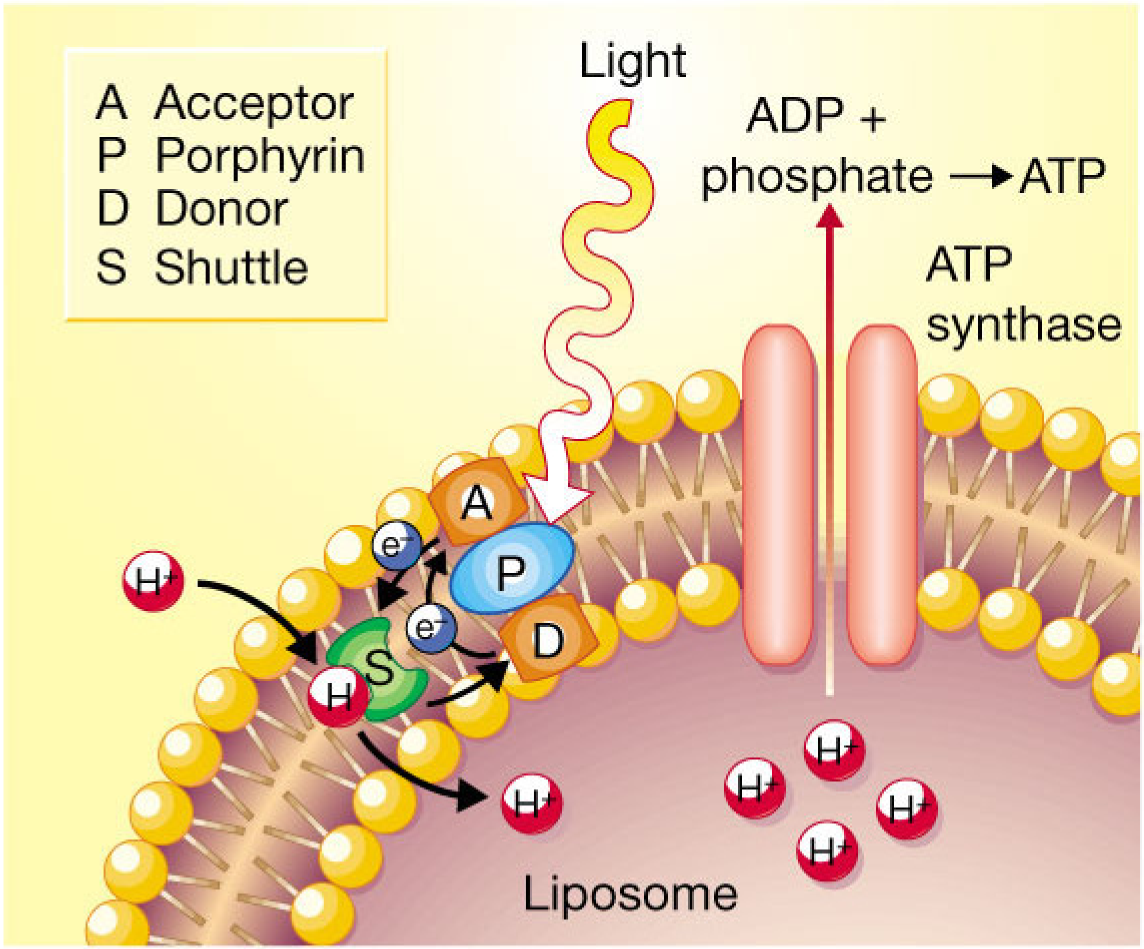


Will These Men Change the World?

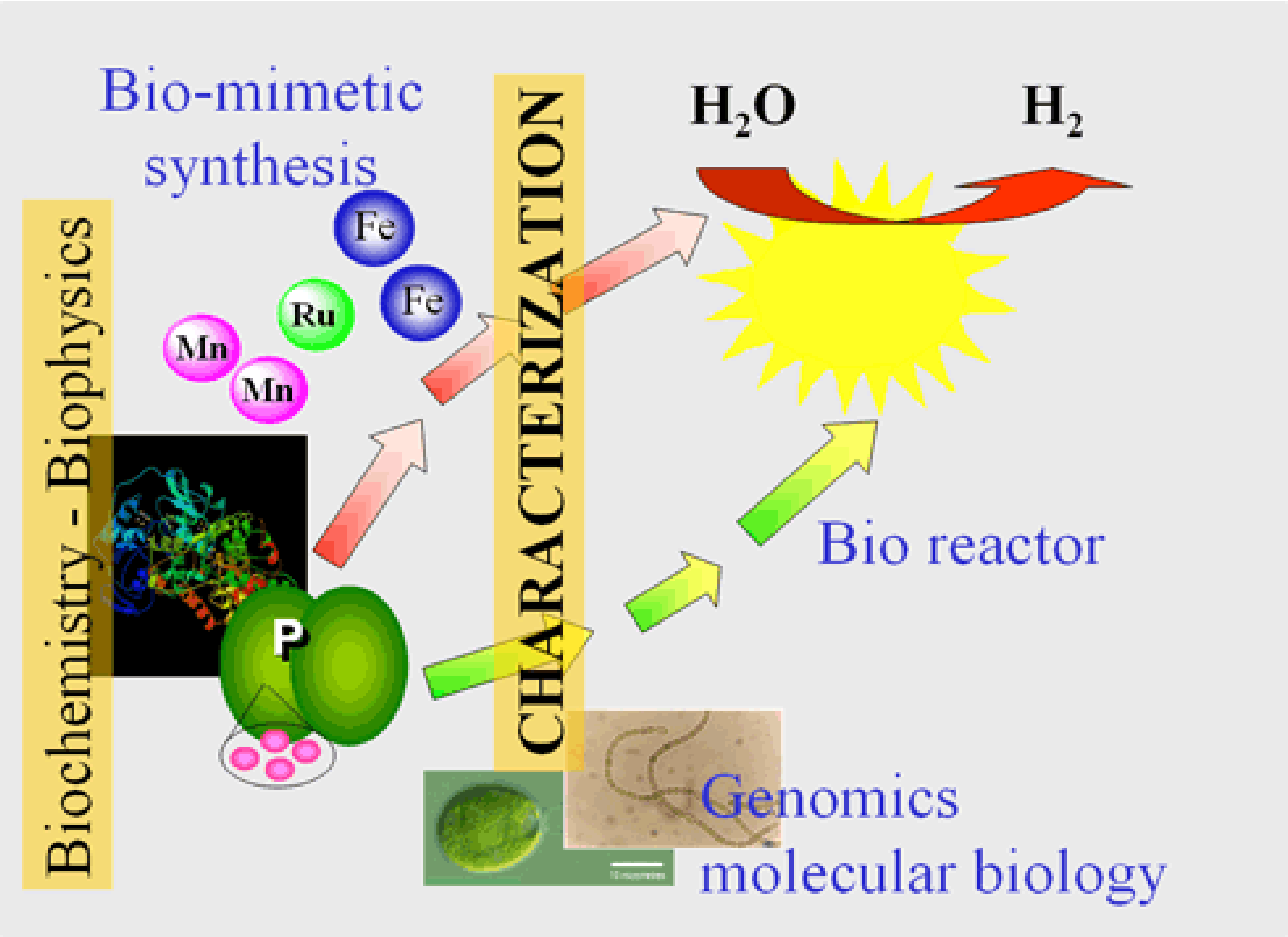




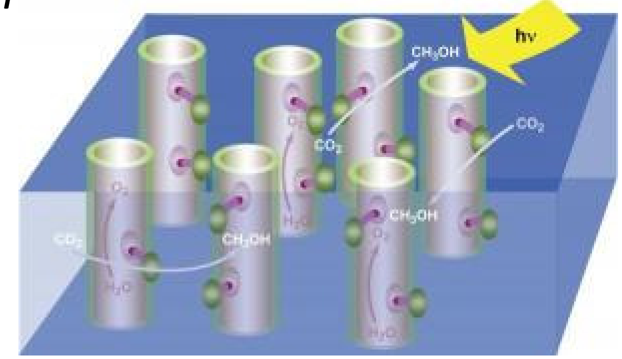
Artificial photosynthesis driving ATP formation in liposomal membranes



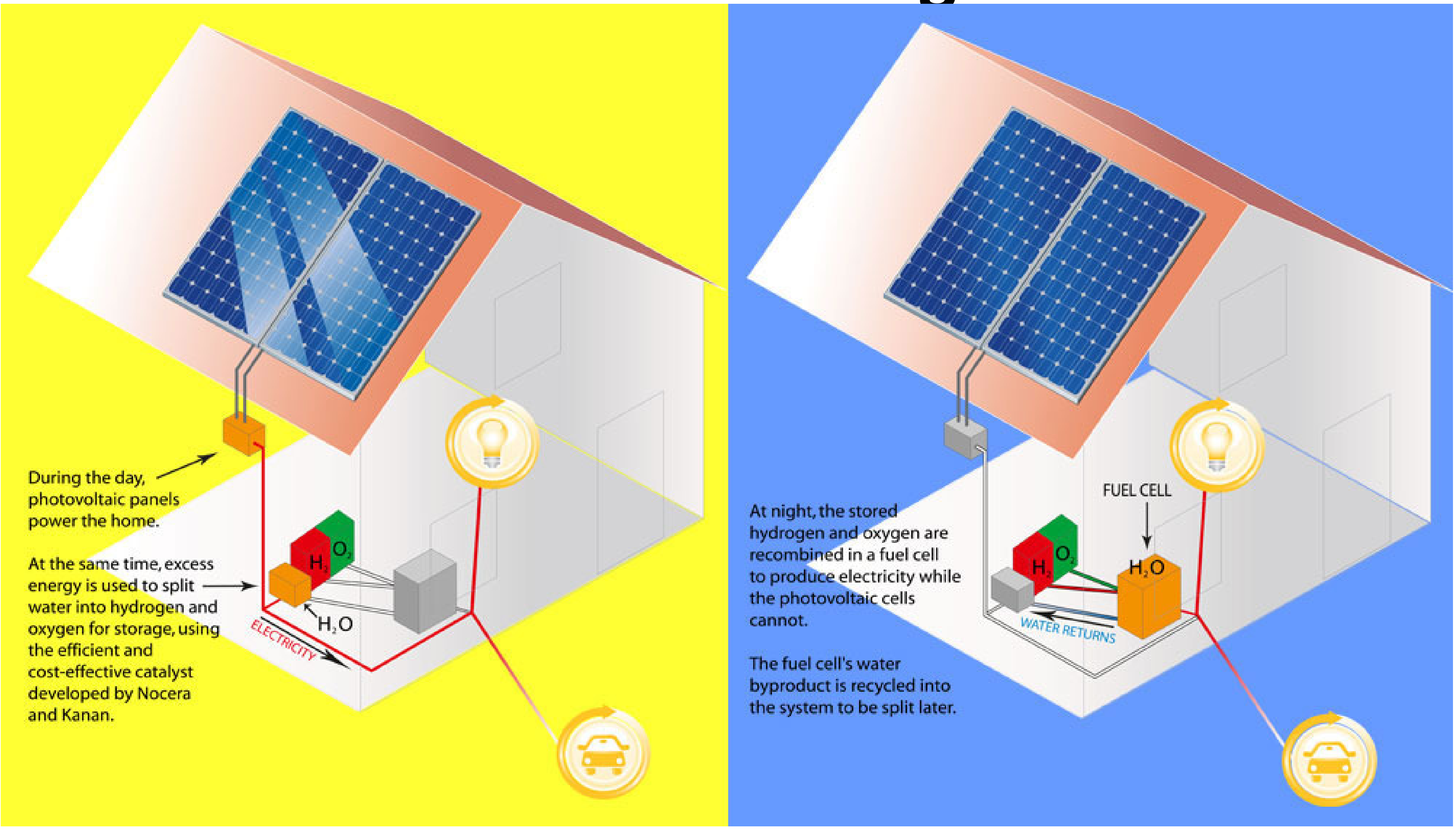
Artificial Photosynthesis



- *Under the fuel through artificial photosynthesis scenario, nanotubes embedded within a membrane would act like green leaves, using incident solar radiation (H^3) to split water molecules (H2O), freeing up electrons and oxygen (O2) that then react with carbon dioxide (CO2) to produce a fuel, shown here as methanol (CH3OH). The result is a renewable green energy source that also helps scrub the atmosphere of excessive carbon dioxide from the burning of fossil fuels. (Credit: Illustration by Flavio Robles, Berkeley Lab Public Affairs)*



Use Artificial Photosynthesis and Nanotubes to Generate Hydrogen Fuel with Sunlight



Things That Can Catalyze Innovative, Boundary-Crossing Research

- **Collaborative Researchers must:**
  - **Think broadly, act personally and manage the innovation mix**
    - Resist falling back on traditional comfort zones
  - **Make the research model deeply different**
    - Pay particular attention to areas of the research where no one is actively innovating.
  - **Force an outside look - every time**.
    - Push researchers to work with "outsiders" more, making it first systematic and then, a part of your culture
  - **Ignite innovation thorough integration of science and technology**
    - Use technology as an innovation catalyst

The Collaboration Gap

Collaboration and partnering is "theoretically easy," but "practically hard to do."

Collaboration requires serious intent.

Having a few beers together is not collaboration.

Collaboration requires discipline

Collaborations need to be encouraged, affirmed and rewarded as part of an institutional plan

Integration of Key Components Necessary for a Successful Program

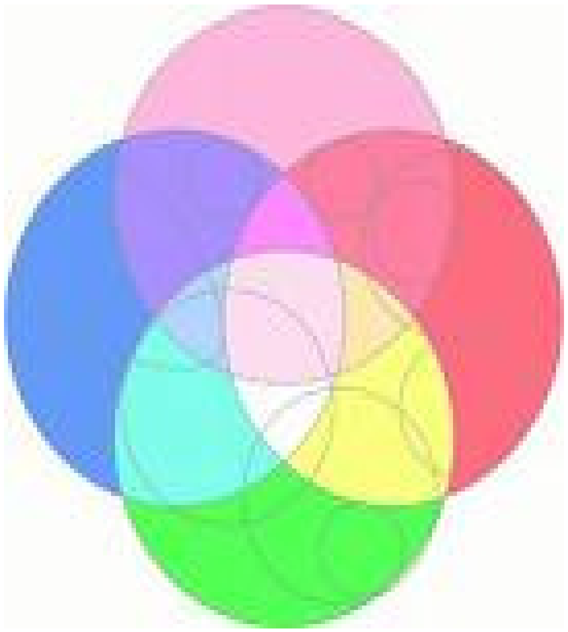
Institutional Support

Committed Faculty

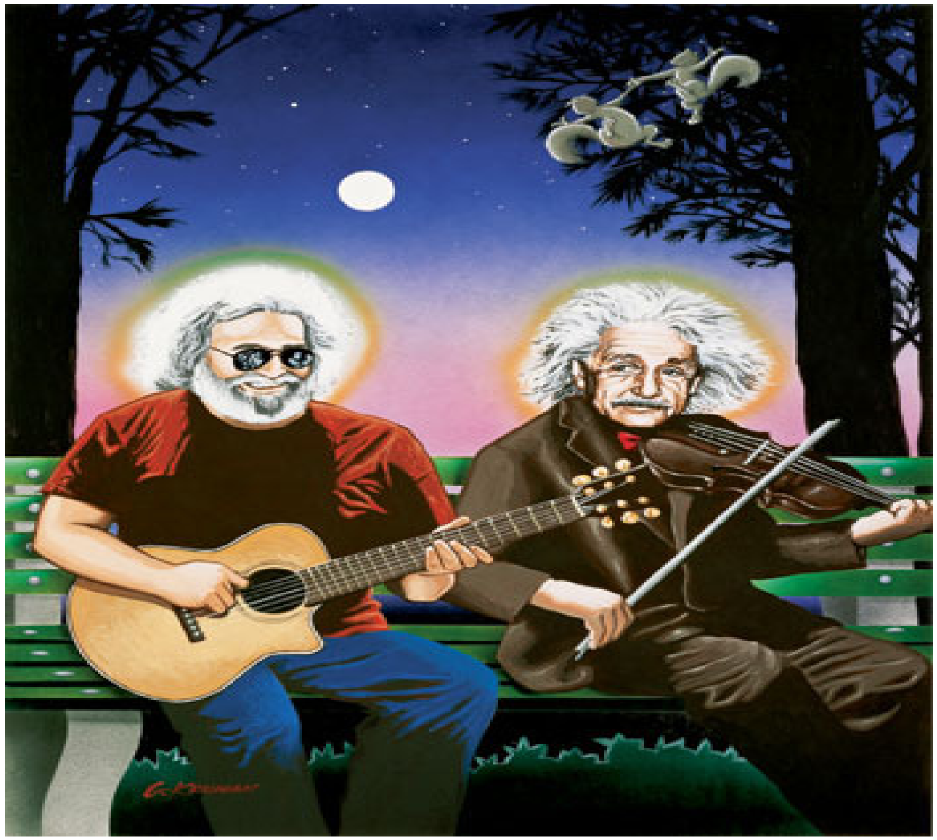
Talented and Motivated Students

Funding

Departments & Programs Willingness to Work to Common Goal



Bottom line is to Form Unique Partnerships to Move Science Forward



……..with the willingness to take risks, to build upon rather than remain cemented in tradition and to embrace, and learn from, failure